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STORAGE

REPORT

ON

WEATHER TELEGRAPHY AND STORM WARNINGS,

PRESENTED TO THE

METEOROLOGICAL CONGRESS AT VIENNA,

BY A

COMMITTEE APPOINTED AT THE

LEIPZIG CONFERENCE.

Published by the Authority of the Meteorological Committee.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE:
AND SOLD BY
E. STANFORD, CHARING CROSS.

1874.

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GENTLEMEN,

I HAVE the honour to submit to you a Report on the subject of Weather Telegraphy and Storm Warnings, which was presented to the Meteorological Congress at Vienna in September, 1873, by a Committee of which I was a member.

To the Report are appended extracts from the replies received by the Committee in answer to a certain circular issued by them, as is explained in the "Prefatory Remarks" by Dr. G. Neumayer, who acted as Secretary to the Committee.

It will be seen that the majority of the replies are from residents in the United Kingdom and its Colonies.

In addition to the replies given in these pages, brief answers were also received from A. Buchan, Esq., Mr. W. Hatfield, His Excellency Governor Rawson (Barbadoes), and Rear-Admiral Schomberg.

To all the gentlemen who have favoured them with replies, I desire in the name of the Committee to tender my most sincere thanks.

I have, &c.
ROBERT H. SCOTT.

To the Meteorological Committee
of the Royal Society,
July 1874.

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INTRODUCTORY REMARKS.

The Programme originally submitted for the consideration of the Meteorological Conference at Leipzig in 1872 contained the following question as its 25th paragraph:—

> "Does the interchange of Weather Telegrams appear so useful that it should receive a fuller development and a firmer organization?"

This question, although not expressly mentioning the subject of Storm Warnings, gave rise to a lengthened discussion at the meeting of the Sub-Committee on Maritime Meteorology, which resulted in the following resolution; No. 5 in their Report to the Conference:—

"The Sub-Committee would recommend that the Conference should, to be in unison with most authorities of science, express itself to the effect that the question of the practicability and utility of Weather and Storm Signals in Europe must still be considered as an open one from many points of view. They would recognise the importance of more thoroughly sifting the material which is in existence, and for this purpose have named a Sub-Committee which should consist of Messrs. Buys Ballot, Scott, and Neumayer, with power to add to their number. All authorities in this branch of science, among whom M. Mohn was especially named, should be requested to give their opinion, and the results of this investigation should be drawn up in a report which should be published at least two months before the meeting of the Congress in Vienna."

This resolution was adopted by the Conference at its meeting of the 16th August, 1872, and in consequence the above-named Committee was appointed, consisting of Professor Buys Ballot, Dr. Neumayer, and Mr. Scott.

Several circumstances concurred to prevent the Committee from taking any actual steps towards the solution of the problem entrusted to them until the commencement of the year 1873. When this period arrived the question was raised whether or not it was advisable to make use of the right of co-optation. This was answered in the negative, chiefly on the ground that all which was requisite was to procure as many competent opinions as was possible, and that such could most effectually be obtained by the issue of a circular, in which the principal points at issue should be submitted to the consideration of such scientific men as, from their position or from the character of their scientific labours, were known to take an interest in the subject.

The next step was the preparation of the questions to be contained in the circular. In respect of these a discussion arose within the Committee concerning the scope of the inquiry which was to be instituted, viz., whether the subject should be treated from a more theoretical point of view, not, however, neglecting its practical bearing, or whether the practical side of the subject of Weather Telegraphy and Storm Warnings should alone be taken into account. The latter view was adopted and the following six questions were embodied in a circular issued to elicit the opinions of competent meteorologists. The questions were issued in English, German, and French.

I.

What are your opinions in respect of the action of the system of Storm Signals hitherto in use, either from your own experience, or from a consideration of the Bulletins published in the United States, in England, and in France?

II.

Is it your opinion that in addition to communications of the direction and force of the wind which is actually blowing, the Barometrical "Gradients" should be given, in order to give warning of approaching wind?

To what should these gradients be referred? viz.:—

a. To the differences between the actual readings at the different stations.
b. To 30 inches, at sea level.
c. To the mean normal heights of the barometer at the stations taken into consideration.

III.

In what way should we take into consideration Temperature, Vapour, &c., &c.?

IV.

If we assume that each Director will institute the proper arrangements in his own district, what do you recommend as the minimum that each Director should communicate to the Director of another district, and should receive from him in return?

V.

Are you of opinion that the present condition of our weather knowledge justifies us in issuing distinct prophecies or forecasts of weather in contradistinction to the simple telegraphic communication of facts, or should we confine ourselves to indications of the condition of the atmosphere in adjacent countries, from which the recipients of the Report must draw their own conclusions? In the latter case should we communicate the general conditions by signals visible from a distance, posting up, at the place itself, the detailed information received from other localities?

VI.

In what way can it be arranged that intelligence of the conditions of weather càn be conveyed to ships at sea, by means of Semaphores or by signals from Lighthouses?

The fact that the negotiations had to be conducted entirely by letter caused an unavoidable delay in the issue of the circular, and it was not until the beginning of May that this could be effected. At that period the circulars were issued to men of note in the special branch of science in all countries, the following being the division of labour adopted within the Committee:

M. Buys Ballot to communicate with France, Spain, Portugal, Holland, Belgium, Italy, and the United States of America.

Herr Neumayer to communicate with Germany, Austria, Switzerland, and Norway.

Mr. Scott to communicate with Russia, Sweden, Denmark, Hamburg, the United Kingdom and its Colonies, &c.

The number of replies received was comparatively small, except in the case of England, as evidently many meteorologists did not feel themselves justified in entering on a discussion on a subject of which they did not possess the practical experience which is requisite for the satisfactory handling of the questions proposed in the circular.

Some of the replies did not arrive until a late period, as was a natural consequence of the great distances over which the correspondence had to be conducted, as *e.g.* to Mauritius, &c.

In order to draw up a resumé of all the answers received, and embody the same in a general report to the Congress about to meet at Vienna, it would have been indispensable that the three gentlemen forming the Committee should have met and arrived at definite conclusions concerning this report. This was, however, impracticable, and on this account the stipulation of the last sentence of the Leipzig resolution, to the effect that the report should be published at least two months before the meeting of the Congress at Vienna, was necessarily left unfulfilled, and it was not until the actual time of the assembling of the Congress that the report was drawn up by the Committee and finally adopted.

Although the report of the Committee (p. 11) as received and adopted by the Congress contains the sum and substance of the evidence collected in the manner just described, it has been deemed expedient, for the development of meteorological science, that the various opinions should be printed in full or in abstract, and circulated as widely as circumstances admit, in order that all those who may wish to judge for themselves shall have the opportunity of doing so. Furthermore, it was one of the first acts of the Permanent Committee, appointed by the Congress at its meeting of the 16th of September, to express an opinion in favour of the publication of the original documents, which were held to afford valuable materials for forming an exact idea of the present state of Weather Telegraphy and Storm Warnings.

In conclusion, little remains to be said in regard of the general arrangement, and the principle on which in some cases action was taken when a *selection* or an *abstract* had to be made. As to the former it is strictly alphabetical; as to the latter, it suffices to say that in the small number of cases of that nature the test has been whether or not, in any special paper, the remarks were pertinent to the questions of the circular. Wherever the answers deviated too widely from the mark a curtailment was deemed justifiable.

(Signed) Dr. G. NEUMAYER,
Secretary.

Berlin, March 1874.

REPORT

OF

SUB-COMMITTEE V. ON WEATHER TELEGRAPHY AND STORM WARNINGS.

The Sub-Committee has adopted as a basis of its discussion the six questions which have been proposed by MM. Buys Ballot, Neumayer, and Scott, who had been entrusted by the Leipzig Conference with the duty of discussing the question of the practicability and utility of weather telegrams and of storm prognosis, and it has arrived at the following results:—

Question 1:—

> What are your opinions in respect of the action of the systems of Storm Signals hitherto in use, either from your own experience, or from a consideration of the Bulletins published in the United States, in England, and in France?

It is sufficiently evident, from the various answers of the scientific men who have been asked for their opinion, as well as from the other official and non-official reports of the individual Directors of Meteorological Institutes, that there is a general conviction of the importance of Weather Telegraphy for the purposes of practical life, and that the existence of such a system is considered a necessity. This is shown from the results obtained hitherto from the systems already in existence.

The Sub-Committee therefore expresses its opinion in the following words:—

It seems desirable that the system of Weather Telegraphy should be developed as generally as possible, and on as uniform a plan as possible. In all countries in which up to the present time such systems have not been organized, steps leading to such an organization should be taken as soon as possible.

The Sub-Committee is further of opinion that it would be desirable to institute this organization on the following principles:—

1. The systems of observation which are already organized or to be organized in the various countries should be in as close relation to each other as possible, and this is of importance, not only with reference to the general arrangement, but also especially with reference to the telegraphic communications.
2. The system of each country must have a Central Office, which, if possible, should be combined with the central office for Maritime Meteorology; but, in any case, like the latter, must be subordinate to the Central Institute in each

country. The observing stations belonging to the system should be placed under the central office for Weather Telegraphy and Storm Warnings, and their officers must be always ready to send to this Central Office weather reports, or to answer its inquiries for information.

3. The observers at the stations belonging to the system must be well instructed, for the purposes of Weather Telegraphy.
4. The choice of a locality as a station for Telegraphic Weather Reports must be made with consideration to all local circumstances and requirements, and with especial reference to the Wind; furthermore, with reference to the series of observations which have already been recorded and reduced for the station, and with reference to the general system. Regard must also be had for the interests of the adjacent systems. But the final decision must always rest in the hands of the respective directors.
5 In order to make the system of warnings as perfect as possible, according to the present state of the Science, the Sub-Committee must indicate that it is desirable that the observations and reports based thereon should be made as complete and continuous (as regards the former) as is possible, *i.e.*, neither Sundays nor holidays should make a difference to them, and there should not be a complete interruption during the night.
6. Representations should be made to the respective Governments to facilitate Weather Telegraphy as much as possible. This is of importance, not only with reference to the expense, but also with reference to time, in respect of the telegrams within each system, and from one central office to another. If Telegraphic Weather Reports are delayed from the consideration of other despatches, the operation of the system will, in the opinion of the Sub-Committee, be seriously interfered with.

It is desirable, in order to carry the arrangements which are required according to the above views, that the respective Governments in granting a concession to a private telegraph company should take care that most thorough regard should be paid to the interests of Weather Telegraphy.

Question 2:—

Is it your opinion that in addition to communications of the Direction and Force of the Wind which is actually blowing, the Barometrical "Gradients" should be given, in order to give warning of approaching wind?

To what should these Gradients be referred? Viz.:

A—To the differences between the actual readings at the different stations.

B—To 30 ins., at sea level.

C—To the mean normal heights of the barometer at the stations taken into consideration.

With reference to this question the Sub-Committee is of opinion that besides communications of the Direction and Force of the Wind, the Barometric Gradients at the time of observation should also be added, in order to give warning of the wind which is coming.

Although the concordance of opinion within the Sub-Committee, with respect to the first part of the question, is great, this cannot be asserted with reference to the second part, inasmuch as the opinions of the scientific men who have been consulted are partly for the mode of reduction given under B, and partly for that given under C.

However, the various opinions within the Sub-Committee have been brought to agreement on this point, that for stations which are not above 300 metres above the sea, the reduction of the barometer readings to the Mean Sea-Level will be admissible. This agreement was attained with special reference to the drawing of isobars for the purposes of Storm Warnings, and in recognition of the theoretical difficulty of carrying out this method of reduction for elevations greater than those named.

Question 3:—

> In what way should we take into consideration Temperature, Vapour, &c., &c.?

With regard to Temperature and Moisture, as well as with regard to Cloud, Appearance of the Sky, State of the Sea and Tides, and Precipitation, it was recommended by most of the gentlemen consulted that some attention should be paid to these subjects, but in what way attention should be paid has not been indicated by any of them; therefore the Sub-Committee is of opinion that this question should be considered as not answered, and it therefore recommends its examination most specially to the notice of scientific men who occupy themselves with the study of storms and their causes, and draws attention to the investigations in this direction by Dove, Mohn, Clement Ley, Peslin, Buchan, and Reye.

Question 4:—

> If we assume that each Director will institute the proper arrangements in his own district, what do you recommend as a minimum that each Director should communicate to the Director of another district, and should receive from him in return?

The answers to this question must be considered as a *résumé* to those given to Questions 2 and 3, and they have frequent reference to communications within one and the same system, but not to the mutual communications between the directors of the individual systems. The Sub-Committee is of opinion that a distinction should be drawn between the theoretical and practical treatment of the question. For theoretical investigations all the elements are requisite and they should all be taken into consideration, but this can take place at any subsequent period.

For practical purposes, with regard to which each director must consider the special requirements in his own country, they must be confined to a minimum.

It is sufficient that each director of a district should receive from his neighbour, as a minimum of what is to be communicated, the following elements:—Wind, according to Direction and Force, Pressure (including the Pressure for the evening of the previous day); Air-Temperature, Humidity, amount of Rain, Cloud, Weather, Sea, and when atmospheric disturbances are approaching, the magnitude and direction of the most important and most recent Gradient.

The Sub-Committee is further of opinion that these data should all be sent reduced, in order that a more rapid treatment of the materials should be rendered possible.

It must be left to the individual directors to determine among themselves the arrangements of a more special nature. This has special reference to the magnitude of the gradient which should be considered as an indication of atmospheric disturbance.

Whenever the International Institution, which is considered as very desirable by the Congress, is called into existence, all the evening observations should be sent to it, in order that a general view of the conditions of the weather of the whole of Europe can be given early in the morning to the individual systems.

Question 5:—

> Are you of opinion that the present condition of our weather knowledge justifies us in issuing distinct prophecies or forecasts of weather in contradistinction to the simple Telegraphic communication of facts, or should we confine ourselves to indications of the condition of the atmosphere in adjacent countries, from which the recipients of the Report must draw their own conclusions? In the latter case should we communicate the general conditions by Signals visible from a distance, posting up, at the place itself, the detailed information received from other localities?

Question 6:—

> In what way can it be arranged that intelligence of the conditions of weather can be conveyed to ships at sea, by means of Semaphores or by Signals from Lighthouses?

From an analysis of the various opinions on the practicability of storm-warnings which have been received, it appears that the great majority have declared *for* Storm-Warnings.

If we give to the opinions of individual societies, as well as to those of prominent authorities on the subject of Storm-Warnings, a weight = 10, to the other practised investigators of this subject a weight = 5, while less experienced men receive a weight of 1 or 2, the result is as follows:—

> For Storm-Warnings of a more or less detailed and decided character, but certainly *above* the simple communication of facts, we find 72 votes. Against Storm-Warnings, and for restriction to a communication of facts, only 24 votes.

The majority of the opinions which have been received tends to the view that these warnings should be given in connexion with communications of facts, only a few hold these communications as quite unnecessary, while other and important voices are only for communication of facts without warnings; but it must be kept in mind that almost all the opinions expressed refer to the north and north-west of Europe, and are only in the first place to be understood as applicable to these districts; in fact the limits should be drawn even more narrowly, it being only the coasts of the districts described which are meant.

On these grounds the Sub-Committee expresses its opinion that Telegraphic Weather Reports have become a necessity, as has been proved by the answers to the first question, and furthermore that the results of the systems which have been or are to be organized for this purpose, can and must be utilized by the communication of simple facts of weather, with such developments, in the sense of storm-warnings, as may be justifiable by the further development of our knowledge of atmospheric disturbances. The results which have been obtained empirically, and by the statistics of weather knowledge, can be utilized for the benefit of navigation and agriculture, &c.

In the present condition of the development of weather prognosis, the matter of most importance is to define as accurately as possible the character of that which comes under the head of communication of facts. Among all the opinions which are submitted there is not a single one which does *not* reject for weather prognosis the title of *prophecies* or *predictions*. The most decided protest is lodged by everyone against the idea of infallibility being implied in this use of such a term. All that is said is, that "an opinion should be given on the weather to " be expected,—or probability of the approach of a storm should " be given—or possibility of prediction of wind, direction, and " force, &c."

In the opinion of the Sub-Committee, a considerable difficulty in the practice of storm warnings consists in the careful avoidance of too special indication of probable wind and weather. The objection which is made by several of the gentlemen whose opinion was asked; that the reports would be discredited, owing to non-fulfilment of the "prophecies," loses its force if only such atmospheric disturbances are communicated, as will probably be accompanied by serious results. Accordingly, warnings by signals should not be issued for winds of forces 5 to 7 of Beaufort's scale, but above those numbers. Such warnings would meet with fulfilment with incomparably greater certainty. On the other hand, according to the experience which has yet been made, only few dangerous phenomena would escape notice. A general rule for storm gradients cannot be given, as many of them will be of a local nature; the director must therefore gradually form his opinion on this question, according to his experience, so that in the opinion of the Sub-Committee it appears desirable that actual storm warnings should not be attempted in newly organised systems immediately after the establishment of the system, but that the director should first gain for himself the experience necessary for the purpose.

If we were in a position to give from time to time, by means of signals, the accurate definition of the communications on conditions of weather, and on the indications of coming weather, the greatest portion of the difficulty would be removed; still we must endeavour to meet this difficulty by notices posted up on flagstaffs, containing explanations of the weather, and the opinion of the director thereon, which must somehow or other be more widely communicated.

This, however, can only have reference to communications in harbours, while for ships passing at a distance, and at sea, means must yet be found to give them an explanation of the signals.

In consideration of all these circumstances, and on the supposition that the conditions indicated in the answers to Question 1, will be strictly fulfilled, the Sub-Committee expresses its views on this very difficult question in the following words:—

1. Communications on the state of the weather should be given by telegraph by the central office to the public daily, and, wherever possible, twice a day, in the first place with reference to the objects of practical life, and especially of navigation.

These communications should be distributed as widely and as rapidly as possible by publication in the newspapers, or by synoptic charts, &c., with opinions on the conditions of the weather. The extent of these communications must be regulated by the means at the disposal of each system, and therefore nothing determinate can be settled on the question.

In case of disturbances in the atmosphere which are expected or have already commenced, telegrams should go to the signal stations, harbour-masters, &c., and rapid distribution must be afforded to them.

2. With reference to these latter telegrams—in cases of atmospheric disturbances—the following distinction may be drawn, according to the opinion of the Sub-Committee.

a. If they are intended for ships lying in larger harbours, in order to afford their captains the opportunity of forming an opinion of a disturbance which is expected, and perhaps has already commenced to be developed, it is possible by a suitable apparatus, perhaps by the *aeroclinoscope* in a somewhat altered form, to bring to the knowledge of the public the conditions of pressure, motion of the wind, &c. Moreover, the receipt of the information must also be announced at the signal stations, and at the open spaces of the harbour, in forms prepared for it, and must be posted up.

While the public, thus interested, obtains an idea of the progress of the disturbance not only at the locality itself, captains, from the movements of their own instruments on board, and from comparison with the telegrams, can form for themselves an opinion on the state of affairs.

b. If such telegrams are intended for harbours for small shipping, fishing, &c., in which case meteorological instruments cannot be supposed to be in the hands of the receivers, any more than a complete comprehension of the rules according to which the disturbances take their course, the apparatus mentioned above can be of little use.

Explanatory notices from the central office, posted up, are therefore above all things necessary, while that office has also to take care that at any very little port of this kind, a barometer and a thermometer are erected at easily accessible places.

3. In consideration of the circumstance that we cannot pre-suppose in the receivers of the communications the degree of meteorological knowledge which is requisite for drawing correct conclusions from the conditions of wind and weather, and from the movement of the meteorological instruments, and, moreover, that these receivers necessarily cannot come into possession of the requisite information until many hours later than the central office,—and inasmuch as the rapid progress of the development of a disturbance hardly leaves them any time for independent prognosis,—and in further consideration that our knowledge, being gained in an empirical way, puts us in a position of being able to foresee for certain districts the course of the atmospheric disturbance, the Sub-Committee is of opinion that the Director of the Central Office should give his opinion on this probable course of atmospheric disturbances which are expected, or have already commenced, not in the form of a prophecy, but in the form of *probabilities.* This opinion must be brought to the knowledge of the public by the Director in question, according to his own circumstances, by the printing and posting up of notices.

It is only when from the conditions of pressure, serious storms of 7–8, according to Beaufort's scale and upwards, are to be expected, according to the opinion of the Sub-Committee, that the views of the directors of the central offices on the direction, course, and force of the storm should be announced by signal apparatus on prominent points of the coast and in harbours and roadsteads.

The Sub-Committee is further of opinion that complicated apparatus cannot be recommended for this object, and proposes, therefore, the use of the drum and cone by day, and the corresponding signal lanterns by night, and recognizes that an expansion of this system of signals, as by the addition of a truncated cone, will be desirable; but under any circumstances the warning signals must be International.

4. In order to insure for these Storm Warnings, which are a benefit for shipping, as great effectiveness as possible, and to avoid misunderstanding, the Sub-Committee considers that the issue of explanations for the comprehension of the signals is very desirable. These explanations should contain, in a series of propositions, explanations of the signals and their meanings for various cases serving as illustrative examples, which propositions can be applied to the several signals in some manner which has yet to be determined.

The Sub-committee is of opinion that while some such course of action would afford protection against misapprehension and discredit of the warnings issued, the public will gradually be educated by it to a clear comprehension of the reality and meaning of weather prognosis.

6.* Such an explanation cannot, according to the nature of the case, be the same for all coasts and waters, and must, therefore, be prepared in consideration of that, but should certainly be international, and added to every Code of Signals.

7.* Finally the Sub-Committee requests the Congress to express its opinion that on the part of the respective Governments, action should be taken to perfect as far as possible the storm-signal system, especially the apparatus and the explanations for the comprehension of the signals, and that special investigations and inquiries which are calculated to promote the signal system should be most warmly supported.*

Reporter, M. NEUMAYER.

According to a resolution of the Congress at the eleventh meeting on the 16th September 1873, the following proposal of M. Hoffmeyer is to be introduced into the foregoing report of the Sub-Committee.

" As it is, in my opinion, of the greatest importance to be able to give the daily meteorological communications as early in the morning as possible, I permit myself to draw the attention of the Congress to the question whether it would not be desirable that these communications should be principally based on the observations of the previous evening. If a well-constituted central institute could receive telegraphic despatches every evening from a sufficiently large number of European stations, in order to be able to deduce from them a resumé of the general meteorological conditions, these resumés could be communicated to the respective national systems during the night, or else very early in the morning, in order to be utilized in communication with the despatches of the individual stations received in the morning.

"The special national systems would, therefore, not only obtain a better and more complete grasp of the circumstances, and of the changes of the great barometric maxima and minima, but by such a centralization of evening observations, it would be possible to content ourselves in each individual system with morning telegrams from a more limited area than at present, when almost every meteorological institute is compelled gradually to extend its meteorological network on all sides, far over the frontiers of its own country, in order to obtain the requisite knowledge of the weather conditions. The telegrams from foreign and distant stations arrive so irregularly and so late, that the daily weather summaries, as well as the storm warnings, cannot be published before noon, or even later, while they could be ready at least two hours earlier if they depended only on the telegrams of a smaller area."

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* So in original; No. 5 is omitted.

EXTRACTS FROM REPLIES.

F. Allison, M.A., Halifax, N.S.

My own experience of Storm Signals is short, but goes to prove that in the present condition of Meteorology much must be left to agents well versed in local peculiarities; and that each large telegraphic centre, such as this, must ultimately be guarded by a cordon of posts to receive and report at extra hours when called. The U.S. system has the great advantage of an immense country, subject to similar influences, but is nevertheless too ambitious; and I prefer the system of Great Britain, which, without an equal advantage of reporting ground, gives results fully as correct. Of the French system I am incompetent to give even so limited an opinion as of the foregoing.

II.

It is my "opinion that in addition," &c., "the barometrical gradients should be given," &c.; these gradients being referred to readings at the different stations reduced to a common sea level—while the *normal* pressure at each station must also be considered by the receiver of warning.

III.

Opens a vast field. Briefly, *Temperature* should have especial reference to mean normal; and to preceding period—whether rising or falling—also to present direction and shift of wind; and, of course to time of day. Force of vapour having been given that of dry air pressure may be known—and relative humidity for comparison, as well as knowledge of absolute existence—in full registers, I doubt the expediency of including these in brief reports. I use the simple wet and dry bulbs, and Guyot's table from Regnault's formula.

IV.

Barometer at sea level; rise or fall. Temperature of air; rise or fall. Weather (as "clear," "cloudy," "heavy rain," &c.) Velocity of wind, and direction.

V.

Better to simply telegraph facts at stated intervals for regular work—say thrice a day. Forecasts (not to be ventured on without much experience) should be left to local agents at chief stations and posted by bulletin with facts of that and communicating stations. Approaching storms, or abnormal disturbance, to be heralded by director of district—not as *prediction* but as *caution*—and signals hoisted, or lowered by his direction.

VI.

Must be answered according to locality. For English or European coasts I could not offer an opinion. Our Nova Scotian coast is well lighted, but the light keepers could scarcely yet undertake this additional duty, and from the wild and frequently inaccessible condition of shore, semaphores would not now be efficient.

H. F. Blanford, Secretary Meteorological Committee, Calcutta.

I.

My experience extends only to the storm signals exhibited in Calcutta for warning the shipping in the port. It is only lately that the system has been extended to that part of the river Hooghly below Calcutta. Its object has been to enable commanders to prepare for bad weather by getting down top-hamper, &c., getting their crews together, &c. It may now be expected to be of further service in keeping ships from putting to sea in the face of a cyclone.

II.

This question has no bearing on our system of signals, which simply indicate that bad weather or a cyclone is probable, or that a cyclone is approaching, as the case may be. The meteorological officer forms his own judgment on this point, the barometric gradient towards the Bay of Bengal being one not unimportant circumstance to be considered. There would be no advantage in giving the barometrical gradients.

III.

In our storms there are no variations of temperature of any importance, since no Polar current in the proper sense of the term takes part in their production. The Himalaya bars access to all Polar currents.

IV.

The actual pressure reduced for temperature and to sea level: the wind, direction and velocity, with weather initials.

V.

As regards the Bay of Bengal, it is impossible in the present state of our knowledge, and with our present means of information, to foretell the probable course that a storm may take, until the wind begins to veer, blowing at the same time with increased force. Since this does not take place until a cyclone centre is within a short distance of a place, stations on the coast cannot be warned of the actual approach of a cyclone, though they may communicate useful information to places in the interior. At Calcutta three or four hours notice of the approach of a cyclone may be thus obtained from Saugor Point at the mouth of the river Hooghly. For such cases a special signal is provided indicating that the cyclone is approaching.

VI.

The ordinary signals (consisting of a single cone, a double cone, and a drum) or lights arranged in similar forms at night time, are as applicable for warning shipping that may be about to enter the river or that have just quitted it as those lying in port.

Charles Chambers, F.R.S., Superintendent, Government Observatory, Bombay.

II.

To this question I should unhesitatingly reply that the barometric gradient between any two stations should be the difference between the abnormals of barometrical pressure at those stations,—meaning by abnormal the excess or defect of the pressure at the moment of observation above or below the normal pressure at the same season and hour. In Europe, however, the diurnal variation is so small as to render it of little consequence whether or not account be taken of the hour of observation.

G. B. Donati, Provisional Director of the Meteorological Service of Italy—Florence.

A telegraphic meteorological service under the Ministry of Marine was established in Italy in April 1866, and placed provisionally under the direction of Professor Matteucci, and in connexion with the Royal Observatory of Florence, where it still exists under the direction of the undersigned, but only provisionally.

This meteorological service is specially and almost exclusively constituted for the benefit of navigation and is organized in the following manner. The places where observations are at present made are the following seaports:

1. Venice.
2. Genoa.
3. St. Rémy.
4. Rimini, &c. (34 stations).

International observatories:

1. Paris.
2. Vienna.
3. Malta.

At 8 o'clock in the morning at all the 34 stations the following observations are made:—

1. Barometer.
2. Thermometer.
3. Psychrometer.
4. Wind-force and direction high and low.
5. State of the sky.
6. At the maritime stations the state of the sea is also observed, and that is very important for the special object in view. All the above-named observations (excepting those of the psychrometer), and even all other observations which may refer to the extraordinary phenomena of the last 24 hours, are sent by telegraph to the central office, where they are properly reduced and entered in a table. A geographical chart is added to this table, upon which the meteorological conditions, corresponding to the day and hour of the observations, are represented by suitable signs and colours.

As soon as the table is made out and the chart drawn, a meteorological bulletin is composed, which consists of a short account of the meteorological conditions of the day, and nearly always ends with a prediction of the weather which will probably prevail during the next 24 hours after the time of making out the bulletin.

In the predictions particular attention is paid to those circumstances which are likely to be of interest to navigation. The bulletin compiled in the central office is despatched by telegraph to the following stations:—

Genoa, Leghorn, Civita Vecchia, Messina, Venice, Ancona, Naples, Palermo, Malta, and on extraordinary occasions, even to the stations of Bari and Cabane.

A copy of the bulletin is posted up at the harbour masters' offices and the telegraph offices of the above-named towns, and published the same evening in some local newspapers, so that the meteorological notices may be made known to those whom they may interest.

The transmission generally takes place about 3 o'clock in the afternoon of each day.

In the case of storms and imminent danger foreseen, extra reports may be given and received, and extended to other places besides those indicated, and especially to the Semaphores, in order that they may exhibit the signals, as we shall presently see.

Besides the observations from the Italian stations above-mentioned, the central office also receives by telegraph the daily bulletin from Paris, a meteorological report from Vienna, and one from Malta. On its part, it sends (always by telegraph) the meteorological bulletin to Malta, the same as to the other stations of the kingdom, and a special report to Paris and Vienna.

It is as provisional director of the Maritime Meteorological Service of the kingdom of Italy that the undersigned replies to the questions proposed by the sub-committee elected by the Meteorological Conference held at Leipzig in the month of August 1872, and which were forwarded to the undersigned by the Observatory of Utrecht, with a letter dated 1st May 1873.

Reply to the 1st question.—After the examination of our own observations, and the French bulletins, which we first receive in abstract by telegraph, and afterwards in full by post, we are of opinion that in many cases we may foretell the storms advancing from the west and north of Europe towards the Italian coasts in time to be of use.

Reply to the 2nd question.—We think that it is not possible to rely exclusively on one or the other of the principles laid down in the second question, but that it is necessary to take all into account, whenever possible; also that we might deduce from the motion of the barometer with a certain degree of probability if the winds which are blowing in the other countries will extend to us, and in doing so, will increase or diminish in force. It appears that it rarely happens that strong winds are not accompanied with a fall of the barometer, while sometimes a great fall is not followed by a violent wind over a large area, but only by heavy rain, with winds which are generally moderate and local. In the meteorological tables which are made daily in this office, in order to compile the bulletin, we note the atmospheric pressure observed at each station reduced to the temperature of zero and to the sea-level; for small heights a fixed correction is adopted, for the others the correction is calculated by tables. We also study the difference of pressure from the previous day at the same stations, and the different heights of the barometer in the various regions of the north, the middle and south, or the west and east of Italy. The normal barometrical heights of the various stations are not determined, for we want the necessary elements. Consequently, even if we wished, we could not follow the method suggested in section C. of the second question.

Reply to the third question.—We pay very little attention generally to the readings of the thermometer and psychrometer in predicting weather; further, the results of the latter are not transmitted by telegraph to the Central Office, by our observers, who only enter them in the registers.

Reply to the fourth question.—We communicate to the harbour masters every day a *résumé* of the meteorological situation and an opinion of the probable weather, even when there is no sign of a storm. They are authorized, however, according to their own judgment, to give warnings to the ports placed under their superintendence, when they think them necessary. In cases of grave indications of bad weather, the semaphoric stations are ordered to hoist the signals established in the International code, and the harbour masters to communicate the forecast of the Central Office to their subordinates. It is desirable that an exchange of notices should take place once a day between all the central offices of the various countries, as is at present done between Florence, Paris, and Vienna.

Reply to the fifth question.—If we knew the meteorological conditions over a great extent of country, and especially those places situated to the south-west, north-west, and north-east of any observatory, we are of opinion that with a certain amount of practice we should sometimes be able to foretell the danger which threatens sailors in time to be of use. The warnings should, however, be given by the central offices to their subordinates, while limiting themselves to transmitting to the observatories of other countries a summary of the general state of the atmosphere and sea on the coasts of the continents and islands of the country forwarding the information.

Reply to the sixth question.—It would be well if the system of signalling which is at present in use at the semaphores were extended to the principal ports, and to the lighthouses when there is no semaphore in the neighbourhood. Moreover, if the semaphores were provided with telegraphic apparatus, they could receive the notices from the central office of the country to which they belong more promptly, and communicate them entirely and gratuitously to the vessels requiring them, as directed by article 29, section IV. of the Regulations for the Italian Semaphore Service. For this reason it would be better to entrust the duty of signalling storms to the semaphores rather than to the lighthouses.

Note.—In the kingdom of Italy the semaphores are placed by Act of Parliament under the Ministry of Public Works, and particularly under the Director-General of Telegraphs, who, with a wisdom greatly to his honour, takes care that meteorological observations are made at the semaphores, and does not regard these observations as his own property, but on the contrary directs that the observations shall be communicated by telegraph or in writing to the Central Meteorological Office of the Ministry of Marine, whereby the observations are much more useful and profitable than if they remained isolated with an administration which, like that of the telegraphs, has little to do with meteorology.

Mons. Fradesso da Silveira, Observatory of the Infant D. Luiz, Lisbon.

I.

Our opinion as to the practical utility of storm warnings at present in use is very favourable, by the examination of the American, English, and French bulletins, the study of each of which embraces sufficient data for deducing very probable storm warnings.

The degree of probability of success is not the same in different countries; and generally it will be much greater in proportion to the extent of the country and its means of more rapid transmission. With respect to this latter condition, suitable measures must be taken. Portugal, for instance, by its westerly position in Europe, is much worse off than Spain or Italy in its conditions for storm warnings, but soon (Aug. 13), being telegraphically connected with Madeira and perhaps the Azores, these conditions will entirely change.

By the simple inspection of the barometric curves of these stations compared with that of Lisbon, we see, in a striking manner, the intimate connection which exists between the storms which pass over Madeira and those which reach our coasts. So that it will not only be Portugal which will profit by these new bulletins, but the less western countries to which it will be able to give very timely warnings.

II.

With respect to giving warning of approaching winds, we do not think it sufficient to rely upon the telegraphic communications as to the direction and force of the winds observed at different stations, but that it is important to be guided by the barometric heights, and its variations (gradients).

These gradients should be calculated with respect to the mean normal heights of each station under consideration (C).

III.

It is not easy to give an opinion or a general rule as to the manner in which temperature and the hygrometric condition of the atmosphere should be taken into account in judging of the direction and force of the probable wind; the geographical position and the altitude of the station in question, its distance from the sea, and the season of the year, have a great influence on the conclusions to be drawn.

The countries bounded by the sea on the south and west are sooner warned of the changes of the wind, by the variations of temperature and humidity, than those in the interior of continents. Thus Portugal, by its position to the S.W. of Europe, is frequently warned as to the duration of the winds which blow from the regions to the north or south, according to the magnitude and the direction of the variation of temperature observed at certain hours in the preceding days.

IV.

There are countries which, by their geographical position, may be able to give very useful warnings to adjacent countries, while they have nothing to gain from the information sent to them in exchange; but we think that besides the telegraphic reports that each country sends daily to a central observatory on the continent, it may exchange with adjacent countries telegraphic reports from some selected stations which may tend to throw much light on the investigations into the march of storms.

For example, in the case of Portugal and Spain, supposing that there is already a cable to Madeira, the Observatory of Lisbon may send to Madrid the reports from Madeira, Lisbon, Oporto, and Lagos, and receive in exchange from the Madrid Observatory the reports from Corunna, Madrid, and Cadiz. For greater simplicity, we may reduce the despatches to whole numbers (tenths and units) which indicate the barometric pressure in millimetres, the direction and force of wind, and the state of the sky by figures from 0—10. Thus Portugal sends to Madrid the following despatches

Madeira	56	S.W.	4·0
Lisbon	60	W.S.W.	2·4
Oporto	59	S.	3·1
Lagos	61	S.W.	2·3

and receives in exchange from Madrid:

Corunna	61	N.W.	3·4
Cadiz	59	S.	4·0
Madrid	10	W.S.W.	2·1

V.

We think that the present state of our knowledge of weather does not allow of our giving actual prophecies or predictions, based solely on telegraphic communications of facts observed, but that with these facts we may give a more or less certain opinion of the march of storms or winds, &c., &c., and that this opinion will be more accurate in proportion to the extent of the area from which we receive reports, and the rapidity and accuracy of the exchange.

As to the last part of the question we think that in the case of communications from the central observatory of the continent to the central observatory of each country, it is sufficient to send information of the facts observed, but in the case of communications from the central observatory of each country to the subordinate stations, we think that conclusions as to the probability of coming weather ought to be sent.

VI.

We think that the measures which should be taken for conveying a knowledge of the conditions of the atmosphere to ships at sea should be by means of day and night signals from semaphores and lighthouses, according to local arrangements.

Perhaps it would be better to employ only one signal, indicating a probable strong wind or storm, without denoting the direction from which it will blow.

F. Gaster, F.M.S., Meteorological Office, London.

I.

My attention has been directed chiefly to the storm warning system in use in the British Islands, and to those warning messages which are forwarded from

England to the heads of several continental meteorological offices. With regard to these there can be little doubt that, for the past few years especially, they have been to a great degree successful, the larger and fiercer gales being generally warned for several hours before their advent. This would appear to be especially true of the worst westerly gales which are felt in Holland. But there can be little doubt also that the warnings are defective in several respects, most notably:

1°. In certainty. Some 15 to 20 per cent. of failures is a large proportion, the successes being sufficiently numerous to command attention, while the failures are sufficiently frequent to arouse opposition from those who are affected by them.

2°. In regularity. The storms follow the warnings at such very different intervals of time that no allowance can be made by those who are affected by them.

3°. In the absence of any indication, beyond what may be vaguely communicated in the words of the telegrams, as to the direction of the coming gale.

4°. In our inability to communicate effectually with vessels a few miles from land, but sufficiently near to render their position unsafe in case of a gale from seaward.

Some of the foregoing defects are of such a nature that they cannot be more than partially remedied even now, but much might be done for the general improvement of the system. For example, I think the reports from many places (notably from many of the French stations) are capable of great improvement both as to the quality and quantity of the information they afford. Many of the outlying stations, too, should have some self-recording barometer (or self-recording aneroid of good construction), and be required to furnish, in addition to readings at certain fixed hours, an account of the changes which have occurred in pressure since the last report.

I have known many cases in which from readings taken at 8 a.m. and 2 p.m. at Valencia, the mercury appeared to be rising briskly at the latter hour, whereas a noon reading would have shown that after rising till midday the mercury had again begun to descend rapidly, and by this means gales have been missed which would infallibly have been warned for by those who were actually suspecting the weather at the central office. Then, again, there is the fact that the period from 10h. a.m. to 4h. p.m. is the only time during which warnings can be sent at present (thus leaving 18 out of the 24 hours unprovided for); and Sunday is omitted entirely.

In warning the eastern shores of the North Sea we are liable to another cause of uncertainty, as the centres of the disturbances which produce their north-westerly or westerly gales frequently lie over the Baltic, and are not even felt by us.

II.

I think that in warning something beyond statements as to wind force should be given. Gradients are very useful, but the most serious gradients accompany rather than precede the gales, so that when telegraphed the conditions will probably have changed materially before the warning reaches its destination. Then again the position of a depression is occasionally such that the only serious gradients will not be shown by any two stations which may be selected. If, however, gradient values are to be used (and the objectionable cases last mentioned are after all exceptional, though real,) let them be referred to actual readings at the different stations (reduced to 32° F. at mean sea level). If instead of this we use *departures from the mean normal heights*, it is true that we get at the amount of disturbing energy, which is developed, *i.e.*, the difference between the disturbed and the average conditions. But it should be remembered that even were the normal conditions to exist at any time there would be wind blowing *at that time*, for the normal conditions of pressure over our islands coincide with a slight gradient for south-westerly or westerly winds. Therefore, if we are to connect gradients with winds we must use actual gradients, not imaginary or altered ones. Then, lastly, if we do this, I can't see why we should use the *departure from an arbitrary value*, such as 30 inches, instead of the departure from zero, *i.e.*, instead of the actual values themselves.

III.

I have not considered this subject as yet with sufficient care to say much, but that temperature should be considered, and that too, much more carefully than it is in most countries I have no doubt. Maximum and minimum temperatures are certainly of great importance, as well as those fixed hours, and in cases when these occur at very abnormal hours, observers should be urged to make special note to that effect in their reports.

IV.

Pressure, motion of mercury in last few hours, temperature, with maximum and minimum, wet bulb temperature, direction and force of winds, ditto of extreme wind since last observation, amount of cloud, general appearance of weather and sea disturbance from certain selected stations. For the last two particulars an additional word or two should be added whenever there is anything locally threatening which the observer cannot express by a scale of symbols.

V.

I think that to confine ourselves simply to "indications of the condition of "the atmosphere in adjacent countries, from which the recipients of the report "must draw their own conclusions," is almost entirely useless. It seems to me, moreover, scarcely right to cast upon the recipients the onus of using for themselves information which (by our silence) we should confess ourselves unable to handle, even though receiving it (as is usually the case) some hours earlier than they do.

Neither do I think (so far as I have been able to gather from long inquiry and study) that we can enter upon a system of "*distinct prophecies or forecasts of weather.*" It appears that some middle course might be adopted whereby the value of the present "Drum" signal might be much enhanced, and at the same time our sailors might be induced to study more attentively the bearing which the general conditions of the weather at places so far distant as Spain, Italy, Scandinavia, England, and the Hebrides have on one another, and on that at intermediate places. Probably it would be well to issue to outports printed instructions as to direction in which the storms which may strike our coasts are likely to travel under various circumstances, and thus give to people at our outports some opportunity of exercising their own judgment with great advantage, or, if informed by wire what the general conditions are favourable for, then with the first signs of a gale they would be better prepared to anticipate its changes, and, if need be, to take advantage of a wind which they might otherwise seek to avoid. To complete the arrangement it would be necessary to expose to public inspection sheets containing such brief explanation as is suggested above. Then so soon as these conditions were established, the fact might be communicated from the central office, and posted up, and not only might warnings of actual storms be issued, with better chance of their being appreciated than at present, but captains themselves would, when acquainted with the system, read to greater advantage the local indications of their own instruments. One can but feel certain that with some such system a most desirable step would be taken towards obtaining more practically valuable storm warnings.

In addition to the more general and extensive depressions, local storms of great severity often travel along a considerable extent of coast,—such for instance as that of the 12th February 1871. With these I do not at present know that we are competent to deal very succeessfully.

VI.

I think this may be left for consideration until we are in a more settled state as to the amount and kind of information we may wish to transmit.

Commission appointed to consider the question of an improved system of Storm Signals for the coast of Germany. Meeting held at Berlin, April 26–May 9, 1873, under the presidency of Professor Dove.

The following are the more important resolutions and expressions of opinion on the part of the members of the Commission with regard to the replies to the six questions contained in the programme.

I.

The Commission is of opinion that the establishment of a system of Meteorological Telegraphy throughout the entire German Empire has become a necessity with reference not only to the further development of meteorological knowledge, but also to the practical utilization of the results. The system is to be connected as closely as possible with the systems of adjacent countries.

II.

The Commission is of opinion that the results of a system so organized can and should be utilized for the communication of conditions of weather in the sense of storm warnings (for the entire German Empire), in so far as they are warranted by the further development of the scientific knowledge of atmospherical disturbances.

III.

As basis for a system of storm warnings for the coast of Germany the following heads were proposed :—

a. Establishment of a central office (Deutsche Seewarte) at a suitable seaport.

b. Establishment of the requisite signal stations, which shall hoist storm signals and announce weather intelligence under the orders of the central office.

c. Establishment of the requisite observing stations on the coast and inland, which shall be in telegraphic communication with the central office.

IV.

With reference to question 5, it was urged by certain members (Director Rümker and Dr. Neumayer) that meteorologists were quite in a position to be able with profit to devote attention to storm prognosis, with reference both to the approach of a storm and to its direction, and that this prognosis has made material progress of late years owing to the intimate relations subsisting between the meteorological institutes of different countries.

If the German central office which is to be founded be placed in close telegraphic connexion with the foreign offices of Christiania, London, Utrecht, and Paris, it would be in a position to detect 24 hours beforehand the great majority of the storms which visit the North Sea, and to warn those coasts in time.

Dr. Neumayer proposed moreover that the Commission should have no hesitation in declaring that the warnings should not be restricted to a simple communication of facts of weather, but that storm warnings should also contain announcements of the direction and force of the wind under the conditions laid down in paragraph II.

5. The Commission at its meeting, May 6, 1873, declared itself unanimously in favour of the maintenance of FitzRoy's signals with cones and a drum, with such modifications as may be rendered necessary by the circumstances of the case.

In addition to the above signals, it seems desirable that for cases in which there is only a general probability of the approach of an atmospherical disturbance, a new signal should be introduced to indicate, "Caution, it is possible that a storm is coming." As such signal it is proposed to use by *day* a spherical *ball*, by *night* three lamps hung at equal distances apart on a vertical line. All lamp signals must give *intense white* and not *coloured* light in any case.

Capt. N. Hoffmeyer, Director of the Meteorological Institute, Denmark.

I HASTEN to send you the following answers to the meteorological questions which you have done me the honour of addressing to me, "on the practicability and utility of storm warnings in Europe."

I., IV., and VI.—In studying the synoptic charts of the weather, which have been constructed at the Danish Institute, and which comprehend the entire of Europe, I have come to the conclusion that one can, so far as this part of the world is concerned, predict with tolerable accuracy the manner in which the greater disturbances of the atmosphere passes over it, but at the same time one is often liable to make great errors in regard to such predictions, seeing that the disturbances are subject to changes so remarkable and so rapid as to the direction and the velocity of their translation, as to their force and their form, that up to this time it has been impossible for me to find exact indications by the aid of which these changes could be predicted.

It appears that the depressions coming from the Atlantic display more regularity in the west and the north-west of Europe in regard to their course and form than they show on gaining the North Sea, the Cattegat, and the Baltic Sea, where the frequent formations of "secondary minima" complicate the condition in the highest degree.

Believing thus that meteorology cannot, except in a few cases, predict with sufficient certainty the direction and force of the coming storm, I maintain on the other hand that observatories receiving every day a sufficient number of telegraphic communications, from a large surface of the globe, will be in a better position to predict the menacing storm, than an isolated observer could be, even had he great practical knowledge of weather and its changes. It is for this reason that I find it good and useful that the observatories should, by suitable signals, give warning of a menacing condition of the atmosphere, but only to "arouse attention."

It might be preferable that the signal should itself illustrate the actual conditions of the atmosphere announcing the storm, seeing that the signification of the signal *in the character of warning and not of actual prediction* would then be better understood. In this case the aëroclinoscope is a solution theoretically happy; but this signal appears to me to have practical inconveniences, and the application would be notably difficult in the countries often traversed by the centres of depression, seeing that in such circumstances the position of the inclined bar should be changed several times in the 24 hours, and would be different at different stations.

I must confess that at this moment I know of no better method of warning than that employed in the English system, where the hoisting of the signal signifies only that the surrounding atmospheric conditions are disturbed in such a way as to cause the belief, according to experience, in the probability of danger, while no forecasts are issued as to the form under which the danger will show itself, nor when it will appear.

I am of opinion that before all, one's efforts should be directed to drawing up the daily bulletins, and that they should be distributed as widely as possible, accompanied by an explanatory resumé. Again, it is of great importance that the public who take an interest in the weather should learn to read these bulletins correctly, by the aid of simple meteorological rules; for instance, Buys Ballot's law, &c. To attain to this it should, in my opinion, be taught in schools, and, above all, in those of navigation.

II. In my opinion the communication of the height of the barometer is of equal importance as that of the wind already observed. When one considers the difficulties of finding suitable stations for the observation of wind, I should even say that the height of the barometer, which is not influenced in the same degree by the localities of the stations, is occasionally to be preferred. As to the communications themselves, I prefer the true barometrical heights (the observations corrected for the influence of heat and altitude). Perhaps one might use still smaller figures in communicating the differences of these heights from 760 millimètres, but, on the other hand, we should leave the complication of plus and minus.

The deviations from the normal heights seem to me of little use, notably for the north and the north-west of Europe, where the normal gradient during the bad season is so great, the average barometrical inclination during the month of January being, for example, according to Buchan's isobars, nearly 8 millimètres from the Baltic Sea towards the north-west as far as the Atlantic; presuming that the force of the wind was in nearly constant ratio to the gradient, it would only be by the "true gradient," and not at all by the deviations from the "normal gradient," that we could know the probable force of the coming wind. Again, it must be noticed that the "normal gradient," theoretically taken, changes from day to day during all the year, and that the normal barometrical height is only known for a number of stations proportionately small.

I think, indeed, that the method of the deviations is not without certain advantages, for instance, with regard to the elimination of the constant errors of the instruments, and also that the stations in the interior of the continent cannot avail themselves of the true gradient without great difficulties; but the prediction of the probable weather, and notably of the force of the wind, is of greater importance for the coasts, where the reduction to the level of the sea is easy enough.

III. I do not consider that I have sufficient experience on this point to entitle me to speak positively. I may, however, observe that the distribution of heat and the quantity more or less great of vapours seem in several cases to have a perceptible influence on the translation and development of depressions, also the condensation of vapours into rain appears to play an important part. For the observers who follow attentively the changes of atmosphere over a sufficiently large surface of the globe, the knowledge of the distribution of heat, of the tension of vapour, and of the general state of the weather, must, in most cases, be of great service in judging of the probable coming weather; on this account, therefore, it appears to me important that these elements should enter into the daily telegraphic intelligence.

IV. One must take into consideration the size of a district, as well as its situation in Europe, in determining how much foreign intelligence it requires to warn it in sufficient time of an approaching atmospheric danger. A small district requires, in proportion, a greater amount of intelligence from the surrounding districts than a larger one, and they ought to extend their outposts by preference in the directions from which, ordinarily, the disturbances advance to the district. As regards Denmark, I think that two or three morning telegrams from the surrounding districts (England, Norway, Sweden, Russia, and the north of Germany) would be the minimum for guaranteeing us against surprises, while I imagine that it would be sufficient to send in exchange two communications abroad. The most important information ought at the same time to be partly drawn from the telegraphic communications of a great central institute giving short resumés of the general situation of Europe, in imitation of those which are sent at present by the Paris Observatory, but comprising a number of stations more equally distributed, and partly from the particular telegraphic communications from the surrounding districts, whenever the state of the weather from their systems show a threatening character (the barometer, for instance, beginning to rise or fall in an unusual manner), in imitation of the weather intelligence of the Meteorological Office of London.

G. T. Kingston, M.A., Magnetical Observatory, Toronto, Superintendent of the Meteorological Office of the Dominion of Canada.

I.

There is no doubt, as regards North America at least, that nearly all storms that are widely spread may be followed in their course across the continent, and that their movements can be foreseen with sufficient accuracy to enable us to warn seaports of their approach.

II.

Communications of barometric gradients, or materials from which they may be deduced, should certainly be given in addition to the direction and force of the wind. Some advantage would result from referring them to normals; but as a knowledge of the normals cannot be procured under several years, it is better that the gradients should be deduced from the heights of the barometer reduced to sea level.

III.

If this question relates to the facts to be telegraphed from stations to the central office, I would say that the temperature of the air should be telegraphed to *degrees*, and the difference between wet and dry to tenths. Telegraphing the readings of both the wet and dry to the nearest degree only is very inaccurate, especially at low temperatures, and if the numbers be given to tenths, the cypher becomes too bulky. I prefer what I have stated to the practice at Washington of telegraphing the relative humidity.

IV.

Apart from considerations of cost, it would be better that the director of each district should receive by telegraph *all* or nearly all the facts collected by telegraph in other districts.

The minimum to be received would be the following from a few selected points :—

(1.) The barometer reduced to sea level.
(2.) The direction of the wind.
(3.) The velocity and force of the wind.
(4.) If a storm of any magnitude be raging, the geographical position of the centre, and the direction and rate of its motion.

V.

I am of opinion that the present condition of our weather knowledge justifies our issuing warnings of probable bad weather, and that these warnings will soon acquire more of the character of predictions. We should not confine ourselves to telegraphing atmospheric conditions, and leave the recipients of the reports to draw their own conclusions. It would, however, be desirable if to warnings or *opinions* telegraphed to a seaport we could superadd a detailed statement of the conditions at a limited number of stations, in order to develop weather study at the port, and to give persons who do study the weather an opportunity of bringing local knowledge into play, and thus determine, more accurately than is always practicable at the central office, the probable form in which the danger will show itself. The extent to which the atmospheric conditions, as distinct from opinion, should be telegraphed to a port must jointly depend on financial considerations, and on the probability of its being properly utilized. The general facts should be published by signals, visible at a distance, while the particulars should be posted up.

VI.

In the Dominion of Canada the warning signal used is a simple drum hoisted on an arm projecting from the head of a tall mast. The drums are of open work, so as to allow a passage to the wind, and are formed either of hoop iron or of a combination of iron and wood. At night a lantern is placed inside the drum, the general glow of which is visible between the bars. At present the drum is to be regarded as merely a warning to *look out;* but it is contemplated to introduce additional distinctive signals, as soon as our knowledge is such as will enable us to do so.

J. K. Laughton, M.A., Royal Naval College, Greenwich.

I.

I believe that the storm drum, as hoisted in our own ports, is fairly correct; but owing to the delay of telegrams, forwarded from many stations only once in the 24 hours, the gale indicated has often in our more eastern ports blown itself out before the drum is hoisted; so that the drum, remaining up for 36 hours, is not unfrequently to be seen in perfectly fine weather. This gives many anxious but ignorant observers an idea that the drum is hoisted without sufficient reason, and tends to render them careless of its warnings. I write this from personal knowledge, having resided for some years past at Portsmouth, and having studied the drum warnings ever since their introduction there.

II.

The actual direction and force of the wind are most important; but the barometric gradient would be a most valuable addition to the warning. It should I think be referred to the difference at the different stations reduced to the same level.

III.

I think that the temperature and humidity of the air, being duly taken into account by the director in forming his "forecast," have no special bearing on the storm signal, so far as the recipient of the message is concerned; and that therefore notice of them would but cause needless complication and expense (see No. 5, *post*).

V.

I am of opinion that the director, having a more extended knowledge and experience than those to whom the warnings are principally addressed, having besides a more copious information than it is possible to transmit as local messages, and being aided in the reduction and arrangement of it by a competent staff, is in a better position for interpreting the indication of atmospheric changes than any person at the ports; that he is likely to make fewer mistakes; and that it is therefore preferable that he should issue the warnings in the more general form, as "forecasts of the weather," rather than a detailed account of the indications on which the forecasts are founded.

VI.

The sub-committee is probably aware that many disastrous wrecks are caused by mistaking lighthouses one for another, and that it has been suggested to make each lighthouse indicate its number by a continual repetition of flashing signals. That some such method should be adopted seems imperatively called for, but there is at present a strong objection amongst seamen to the proposed change. They argue that a fixed, a revolving, or a flashing light can, and ought to be distinguished at a glance, and that to make all lights flashing would lead to fatal confusion; also that the flashing signals, easy enough to anyone in constant practice, are easily forgotten, and would be simply an unknown language to the master of a ship coming home from a long voyage. Considering these objections, which seem to me well-founded, notwithtanding my sense of the great necessity of some change in the existing system, I do not think that any attempt to introduce other and less important signals into the lights would meet with favour from the nautical world.

Major-General Lefroy, F.R.S., Governor of Bermuda.

I.

I am of opinion that the storm signals are of frequent value, and as more experience is gained will become more valuable. Unmistakable indications of an approaching hurricane were afforded by the surf at Bermuda on the forenoon of Wednesday, August 20th, 1873. The hurricane centre itself did not reach this latitude before 6 a.m. on Saturday 23rd. Had any means existed of telegraphing to the United States or Nova Scotia in such terms as to have caused the display of storm signals, the great loss of life and property which occurred on the 24th might have perhaps been very materially reduced.

II.

I think the gradients should be given reduced to 30 inches at sea levle. Stations being irregularly distributed, plan A seems to be less easy to interpret than absolute measures. Plan C has very many recommendations. Many years ago (about 1850) I published in the " British America Medical Journal " monthly abstracts of the meteorological registers at Toronto on this principle, *i.e.*, showing the temperature of the air, and if I remember right the barometric pressure in the form of ± differences from normal mean values carefully determined; but the plan did not appear to find favour, and after a year or two was discontinued.

III.

As there is no approximately uniform temperature at the level of the sea, as there is an approximately uniform pressure, and as thermometric readings mean nothing unless in relation to permanent conditions proper to each locality, I am of opinion that the temperatures should be given by ± differences from approximate means proper to the place, month, day and hour, which means should not aim at the precision implied by a second decimal, and be revised periodically, perhaps every 10 years. I do not think that for such purposes as storm signals it is very important to give the vapour; but if given I should prefer terms of saturation, as 100°.

IV.

All the elements at two hours of absolute time daily, to be identical over provinces, *i.e.*, areas as large as possible, so as not to throw any of the observations upon inconveniently early or late hours of local time. The communications to be multiplied only when disturbances of the atmosphere seem to call for it.

V.

I am of opinion that distinct forecasts or prophecies should always be ventured when the facts are of a well-marked character. When the facts are not well marked, and the prediction is in such vague terms as to mean little or nothing beyond the proverbial uncertainty of weather, I would dispute with it.

VI.

I think that lights, whether fixed, flashing, or revolving, might be provided with some extra flashing apparatus which should give a universal signal of warning to vessels in view. It would, I think, be impossible to make it explicit or self-explanatory. It would mean in words—

Vessels are notified that, from indications known to us, precaution is recommended on this coast; or more briefly, " Look out for squalls!" without attempting to indicate from what quarter. But during daylight I think something more explicit might be attained by the use of cones or shutters visible for a few miles.

C. Meldrum, M.A., Observatory, Mauritius.

I.

The systems of storm signals hitherto in use have, in my opinion, been of considerable utility, and I think it is of great importance that they should be improved and extended as experience may suggest. This, however, cannot be done without adequate Government support. If the various Governments were to make weather telegraphy co-extensive with the network of electric wires and cables over the surface of the globe, not only would navigation, commerce, and agriculture reap immense advantages, but the facilities thus afforded for studying the weather as it existed at the same moment over a great part of the world would in a few years do more to promote our knowledge of atmospheric phenomena than centuries of labour and countless isolated facts and observations have hitherto done. If Mauritius were in electric communication with some of the other islands in the Indian Ocean, storm warning here would be almost perfect. As it is, our storms are of so simple and uniform a character, compared with those of Europe, that their bearings, approximate distances, and courses may be, and actually are, ascertained from observations at a single station, and publicly announced from day to day until the danger is over. So far as my experience goes, no hurricane has ever passed near Mauritius without its having given ample warning of its existence and progress.

II.

I am of opinion that in addition to the direction and force of the wind the steepest "gradient" should be given, and that it should be referred to the difference between the actual readings at two stations. If the barometrical readings at all the stations, together with the altitudes, &c. be given, and the distances be known, of course the gradients may also be known. In any case, I think it would be well to give the greatest gradient for a distance (say) of 50 miles. This would afford some idea of the probable violence and extent of the storm. (The difference between the actual readings must be corrected for the difference of altitudes. I would take the mean normal difference of the barometers for this correction.)

III.

Temperature, vapour, humidity, and dew point are of secondary importance in judging of the existence and course of storms near Mauritius. As collateral evidence they are sometimes useful; but the barometer, the direction and force of the wind, and the character of cloud, afford the principal indications of a coming cyclone. Generally the temperature is comparatively high before the setting in of a hurricane, while the tension of vapour and the humidity are comparatively low. As the storm approaches the weather generally becomes showery and gusty, the temperature begins to fall, and the vapour tension and the humidity begin to increase. But even if these signs were absent, a falling barometer, an increasing wind from the S.E., and the appearance of high white cirrus and cirro-stratus clouds, gradually overspreading the sky, and ultimately deepening into nimbus, would be infallible indications of a hurricane at a distance. During the earlier part of the passage of a Mauritius hurricane the wind is invariably polar, and during the latter part equatorial; and the vapour tension and humidity are greatest with the northerly and westerly winds, that is, in the equatorial current. By this time, however, the centre has passed and the danger is over, so that the increase of vapour tension generally comes too late to serve as a warning. In Europe, where storms have very frequently an easterly progression, and the wind often sets in as an equatorial current from the S., an increase of temperature and vapour tension might afford valuable premonitory information, whereas a decrease of these elements might indicate the approach of a polar current, and the setting in of a storm having a westerly progression. In short, as in both hemispheres the polar current forms the front of storms travelling to the westward, and the reverse takes place in storms travelling to the westward, I think that changes of temperature and vapour tension in Europe, where variations of these elements are greater and more sudden than within the tropics, might afford indications of the character and course of a coming storm, and that they should be taken into account until proved to be useless.

IV.

The minimum should be, (1) the atmospheric pressure and temperature, (2) the direction and force of the wind, (3) the amount and character of cloud, and (4) the vapour tension, all as observed at principal stations, and, if necessary for filling in, (1) the atmospheric pressure and temperature, and (2) the direction and force of the wind, as observed at secondary stations.

V.

It is clear that our present knowledge does not justify us in issuing distinct prophecies or forecasts of weather in the sense in which predictions of astronomical phenomena are issued. Their science not having arrived at the perfection of a deductive science, meteorologists must necessarily confine themselves in a great measure to a simple statement of facts. I am of opinion, however, that each statement of facts respecting the existence of bad weather should, if possible, be accompanied by a statement of *probabilities* as to what may fairly be expected to happen. Without some attempt of this kind the facts will likely long remain comparatively barren. If those who professionally occupy themselves with weather changes, and have the best possible means of forming a judgment as to what is or is not likely to occur, can draw no useful inference from their previous experience and the facts before them, they should, of course, simply communicate the facts; but if they have very good reasons for supposing that a certain storm will take a particular course, and that certain districts are much more exposed to danger than others, I think that the public, who may be supposed to be less able to draw conclusions from the facts, should have the benefit of their opinion; it being distinctly understood that such opinion is not a prophecy or a prediction, but an inference which may turn out to be wrong, although the chances are that it will be found to be correct. The success which has lately attended storm warning (the failures in England are now reduced to about 20 per cent.) furnishes, in my opinion, strong evidence in favour of communicating "probabilities." Such communications would not only enhance the interest and value of the bulletins, but tend to stimulate and sustain the attention of the directors. The chief guide in the ordinary business of life is not mathematical certainty but probability, and I do not see why, in the absence of invariable law. the same principle should not be acted upon in the case of storms. The only question is whether or not in European storms there are such preponderances as to their courses, &c., and such interdependence among their phenomena, as to warrant the issue of probabilities. (That is, whether the amount of probability is so great as to be of practical use. If it were known that out of 100 storms which made their appearance in certain localities and under certain conditions, 75 would pursue a certain course, the probability in favour of one storm taking that course would be three fourths of the whole number of chances, and a knowledge of this might be very useful, whereas if the number of favourable chances were much less, no inference of practical value could be drawn. With the exception of the aid that Buys Ballot's law may afford, the question is entirely one of experience, and as the experience of one country may be very different from that of another, it may be impossible to lay down any general rule on the subject.)

As regards Mauritius storms our only difficulty is the uncertainty as to when and where an advancing cyclone may recurve. In England the whole problem is much more complicated, and the difficulties there are rendered still greater through the want of stations farther west which might give warning of the approach of the numerous storms that come from the Atlantic. These storms sometimes travel so fast that they pass over the British Islands before there is time to receive warning from the westernmost station and to communicate it to the outposts. This has long ago been clearly pointed out by Mr. Scott, and it would appear that unsuccessful attempts have been made to overcome the difficulty by establishing a station at the Azores and mooring a vessel at the entrance of the Channel. Judging from the courses of some British storms traced by Captain Toynbee and Mr. Buchan, and from a knowledge of analogous storms in the southern hemisphere, it seems to me that the Azores are too far south for affording warning to England, and it may be that the entrance of the Channel is not sufficiently distant. The remark made by Mr. Scott in his recent lecture at the Royal Institution, that "if it were possible to place " the Meteorological Office, with its present telegraphic facilities, on the west " coast of Ireland, we might fairly hope to foretell *five sixths* of the storms " which strike the British Islands," not only shows the practicability and advisability of issuing weather probabilities, but points to the importance of establishing one or more floating observatories to the westward of Ireland. The experience of Prof. Mohn and Herr von Freeden on the continent furnishes similar evidence. The latter observer states in his Report for 1871, that " it " can be proved from our daily weather reports that out of 23 storms felt in " Hamburg during the year, 22 had *come across the British Islands*." These storms, therefore, must have come from the westward, and if Hamburg had not had warnings from England, there would have been as little time for her to prepare as there is in London. On the other hand, it appears that the reports from eastern Europe give the Meteorological Office in London "most important data for anticipating the approach of storms from the *northward or eastward*." (Report of Met. Com. for 1870.)

I am therefore of opinion that, when possible, along with a statement of facts, a statement of probabilities should be issued, and that to render the latter of greater value for England, Hanover, Denmark, Norway, &c., it is important that floating observatories should be established to the west and N.W. of Ireland, and connected with the shore by electric telegraph. (The establishment of floating observatories, however desirable, may be impracticable.)

The general conditions of weather should, I think, be communicated by signals visible from a distance. With a statement from head-quarters as to what is likely to occur, I do not think it would be necessary to communicate to seaports, &c., details of the observations received. Except to specialists these details would probably be of little interest. They would of course be published in the newspapers.

VI.

I can scarcely offer an opinion on this subject. I should think that intelligence should be conveyed to ships at sea by signals from lighthouses and other prominent places, and that the signals should be the same as those used in announcing danger to the seaports.

The Meteorological Society, London.

I.

We approve of the present system of storm warnings, as far as it goes, but think it a great inconvenience that the provision made for giving intimation of storms is limited to six days only of the seven.

We would recommend that observers should be encouraged (by small rewards) to send notice of special and sudden changes to the central department.

II.

We are of opinion that barometrical gradients should be given, and that the readings being reduced, they should be referred to sea level.

III.

When any sudden temperature—and vapour—changes occur, or when an abnormal state presents itself, these should be signalled as important in connexion with storm signals.

IV.

We think this must be a matter for private arrangement between the directors of the various districts.

We would suggest, then, in addition to the ordinary numerical data, special gradients, or exceptional temperature, should be notified.

V.

We are of opinion that in addition to the inclined arm, showing the gradient, a ball might indicate temperature, and the drum and cone wind; also that a short summary of the expected weather should be sent with the telegram stating existent atmospheric conditions.

VI.

The aëroclinoscope and the drum and cone might be hoisted on lighthouses and lightships, in addition to those on shore.

Professor H. Mohn, Meteorological Institute, Christiania.

The possibility of foretelling weather depends upon our knowledge of the motions of the atmosphere, and on the changes in these conditions in general. The sole periods which we know, the daily and yearly periods in the various meteorological elements, are in our regions so often disturbed in their regular course, that the knowledge of them has only a slight importance as a basis for weather prophecies.

Much sooner, therefore, are the chief subjects of such prophecies the non-periodic variations from the normal conditions, since these conditions only seldom appear in nature, and that only in the change from deviation in one direction to deviation in another.

The simultaneous condition of the various meteorological elements which produce that which we call weather, shows that it is mainly dependent on the wind. It is from the different kinds of wind-roses that we learn this dependence. When the wind-roses are calculated even for short periods, as for months, nature sometimes brings to our notice other variations from the average conditions than the normal ones. But on the whole it is a result of the wind-roses that the wind, according to the direction at the same time of the year and day, and at the same places, preserves its character in such a way that we may consider the wind as near its definite cause for the character at the time of the other elements. It is another thing that the same character of the weather may be produced by winds from different directions, even at places which are close to each other, or that the same direction of the wind at stations close to each other can produce different weather ; but this depends upon local, viz., topographical conditions, which bring a wind of a certain character by different paths to different stations of observation.

The first condition which determines the direction and force of the wind, according to the most recent meteorological inquiries, is the distribution of pressure. In accordance with the properties of the air as an elastic and heavy body, has a constant tendency to arrange itself in strata of density and pressure decreasing upwards, which arrange themselves normally to the action of gravity. The inequality in the pressure of the air thereby produced would indicate the condition of equilibrium if it were attained at any moment, and would show us strata of equal pressure parallel to the surface of the sea. But if, as is always the case, the pressure at the same height above the sea level is unequal, then we see how the air is set in motion from the places where the pressure is higher to places where it is lower, in accordance with the rules for the motion of gaseous bodies.

The relation between the wind and the pressure of the air becomes intelligible if we consider the distribution of pressure at one and the same level. This is attained most easily by reducing the heights of the barometer which are not too high over the sea to its level, entering them on charts and drawing isobars.

Under *direction of the barometrical gradients* I understand the normal to the isobars drawn from the higher to the lower pressure; under the *magnitude of the gradients* I understand the number of millimètres by which the pressure, reduced to the level of the sea, would be lower if you travel over a definite distance, *e.g.*, a geographical mile in the direction of the gradient. By the direction and magnitude of the gradients the distribution of the pressure at a place is completely determined. In a horizontal plane the variation of pressure is greatest along the gradient, and is perpendicular to this direction. For every intermediate direction it is proportional to the cosine of the angle intercepted between this direction and the gradient.

The difference in pressure at the sea level, or on the surface parallel with it, which is indicated by gradients, is an accelerating force which tends to drive the air in the direction of the gradient with a velocity in some measure proportional to the magnitude of the gradient; but the motion of the air, as a rule, does not follow the direction of the gradient, for there are forces which cause it to diverge, viz., the rotation and spherical form of the earth, which in our hemisphere produces a deviation towards the right, in proportion to the sine of the latitude, and is similar in all azimuths, together with the centrifugal force of the air, which acts as a disturbing force when the air has a motion along a curved line. Around the barometrical minima where the paths of the air are spirals which turn towards the minimum, the centrifugal force acts in the same direction as the earth's rotation. Around the barometrical maxima where the air paths turn away from the maximum, the centrifugal force acts in the opposite direction to the earth's rotation, and the deviation of the wind from the gradient is less.

The motion of the air is constantly meeting with obstacles which oppose an acceleration of motion and tend to produce uniform motion. The obstacles are of various kinds, and so are their actions. Hence for one and the same gradient we have a velocity of wind which is greater in the higher strata than in the lower, greater on sea than on land, on plains than on mountains. *Cœteris paribus* the velocity of the wind seems in some way to be proportional to the magnitude of the gradient.

The exact rule for the proportion of the wind to the gradient has not yet been determined, either empirically or by theoretical mathematics. So much we can say, that the direction and force of the wind at any place depend on the local gradients and the local obstacles, and do not (neglecting centrifugal force) depend on the conditions of air motion at other places and at other times, for the sluggishness of the air is too slight compared with the obstacles which oppose its motion on the surface of the earth.

While I thus refer the weather to the direction of the wind, and the direction and force of the wind to the local gradient, and to the local conditions of surface, our next task is to determine the direction and magnitude of this gradient, with its changes at various places, *i.e.*, to determine the law of the variation of pressure. If we knew this law, we could, if we had a distribution of pressure on the surface of the earth given to us by simultaneous observations, further calculate what these conditions should be at any succeeding or previous epoch of time, in the same way as from the osculating elements of a planet path we can calculate the place of the planet at any time. From the distribution of pressure, we could thus again, by paying attention to the local conditions, deduce the wind and weather of the various localities.

The chief problem in meteorology is, then, the law of variation of pressure; at present we can only say that we are standing at the threshold of its discovery. We can see various causes which are acting in increasing a pressure or reducing it, but the quantitative treatment of the matter remains among the entirely unsolved problems. We are not able by calculation to find how pressure varies at each place, and in this way to determine how the gradients at each place vary in direction and magnitude. Similarly we cannot calculate the direction and force of the wind which is to be expected any more than we can the weather which is to be expected. We are, therefore, driven to form an opinion based on the one side on given data observations which indicate the condition at any time, and on the other hand, is based on the very slight knowledge which we have, in a qualitative way, of the change of pressure.

If we seek to improve our forecasts and storm warnings, there are two ways in which we can attain this object. One is to develop the theory of the variation of pressure and the law of the winds; the other is to develop the technical assistance which offers us the basis on which our decision or our calculation must rest. The development of the theory cannot be hastened artificially, for it must wait the development of our science. It can only so far be assisted that meteorologists shall see the importance of the chief problem, and direct their efforts in this direction. Thus we are at the present time occupied with developing the technical modes of operation; in this subject something, and perhaps much, may be done by a sufficient supply of funds.

We should have a system perfect from the technical point of view. If we had a series of meteorological stations lying at suitable distances from the central station, and telegraphically connected with it in such a way that the instruments of each station recorded their indications at the central station, at this latter we should be in this way in a position to construct a synoptic chart for every instant. We should be able to trace the synchronous changes of all elements, as well as those gradients which produce them. Drawing conclusions from the continuity of the variations we should, for the immediate future, determine these variations with a reasonable amount of certainty, and in this way always have a warning, and could also issue warnings to the stations of approaching changes in weather and wind, its direction and force.

Such a system might be imagined, although its activity might sometimes be interrupted by the failure of the instruments or of telegraphic communication. But it would be connected with such a cost as we can never hope to have placed at our disposal. We must, therefore, content ourselves with reducing our demands.

Firstly, we refer to the existing telegraph lines; these do not exist as yet in all places from which it would be of the greatest importance to obtain intelligence for weather forecasts. For instance, the Färoes and Iceland. Secondly, the actual telegraph lines are so occupied with private correspondence that they, independently of the cost, can only be to a very small extent employed in the service of meteorology. This circumstance hinders us from adopting places which might be of great use to us into our telegraphic network of stations.

In Norway, meteorological telegrams are the first which are sent in the morning from the observing telegraph stations to all ports. An arrangement is so organized that all its places receive meteorological information almost at the same time. But we had to give up the idea of meteorological morning reports from places like Tromsö, Alten, and Vardö, which would be of great interest, because owing to the great distance, such reports of the wind would not reach southern Norway before the correspondence was in full course and our lines in southern Norway entirely occupied.

A necessary condition for the development of our system of weather telegraphy towards our most northern provinces is the erection of several telegraph lines in southern Norway.

Within the circle of stations which are connected telegraphically, we are, in consequence of the cost, compelled to make a selection of stations which is decided by the position of the stations, their local circumstances, their more or less easy and certain connexion with the central station, and the quality of the observer. From the British Isles we receive reports from Thurso, Yarmouth, and Valencia. This number from such an area I can only consider as a minimum for a useful system of storm warning.

Instead of constant reports throughout the night and day, we must content ourselves with one, or at most two reports, and these only from a few individual stations. For our circumstances we only choose a morning hour and an afternoon hour in addition, but our experience teaches us that the condition of the atmosphere in the course of 24 hours often changes itself in a different way, or to a greater degree than we could conclude from the conditions given in the morning, in combination with previous conditions. The result is that storms come on us unexpectedly when the previous signs have not shown themselves in the morning, but later in the day. The scanty afternoon telegrams are of some use in this direction, but not enough.

The Norwegian system of warnings has the following arrangement. The Meteorological Institute at Christiania receives daily, with the exception of the

British Islands on Sunday, the following meteorological telegrams. From the Norwegian stations, Bodö, Christiansund, Florö, Skudesnaes, Oxö, Sandösund, and Dovre, barometer reduced to zero and sea level, dry and wet thermometer, direction and force of the wind, cloud and character of precipitation, height of the sea at coast stations at 7 o'clock in the morning in summer, and 8 o'clock in the morning in winter. From Bodö, Christiansund, Skudesnaes, and Oxö, a report of similar contents for 8 o'clock in the evening is sent. These telegrams are, as a rule, received at the Institute between 9 a.m. and noon.

From the Swedish stations, Haparanda, Hernösand, Stockholm, and Wisby, reports of the same character as the Norwegian (but without sea-disturbance) for the hours of 7 or 8 a.m., and in addition, barometer and wind for the previous evening. They arrive at the same time as the Norwegian reports.

From the Danish stations, Copenhagen and Fanö, the same reports as the Swedish arrive at 8 in the morning.

From Thurso, Yarmouth, and Valencia, according to Mr. Scott's code, at 8 a.m. Greenwich time, arrive at noon.

From the Swedish stations, Oregrund, Ystad, Helsingborg, and Warberg, together with Frederikshavn in Jutland, containing wind, and partly also weather for 8 a.m., come in the morning.

From Thurso for 2 p.m., according to Mr. Scott's code, and from Skudesnaes for 4 p.m., containing barometer, thermometer, wind, weather, and sea, arrive in the afternoon.

From Paris the bulletin of the Observatory arrives in the afternoon, but often even later.

As soon as the telegrams reach the Institute, the necessary reductions and calculations, *e.g.*, vapour tension and relative humidity, are made, and all are entered on forms.

On a chart we enter the height of the barometer in millimètres reduced to zero and sea-level, the direction and force of the wind by arrows, cloud, precipitation by symbols, with vapour tension in millimètres, and the sea-disturbance in numbers. Isobars are drawn at the same time for all stations, which give the height of the barometer on the previous evening; at Bodö, Christiansund, Skudesnaes, Oxö, Christiania, Haparanda, Hernösand, Stockholm, Wisby, Copenhagen, Fanö, Thurso, Yarmouth, and Valencia, the change of the barometer from the previous afternoon to the morning of the day is given. After these changes, with the addition of the absolute readings, and the changes of the other meteorological elements which the telegrams give, we form a decision on the probable change of pressure in the course of the day, and subsequently on the probable changes of wind and weather.

As soon as the Norwegian, Swedish, Danish, and British telegrams arrive and are entered in the chart, we prepare a report of the conditions, in connexion with which we draw a forecast of the weather probable in southern Norway. This report is published in the Christiania daily papers. At the same time the form which contains the observations is posted up in a few open, frequented places. The Norwegian morning telegrams are exhibited even earlier by the director of the telegraphs, as is done at all the harbour stations, the authorities of which give a yearly subscription to the telegraph service.

If the condition is such that there is fear of a storm, a storm-warning telegram is sent to all the telegraph stations which are threatened, with a statement of the time of issue, and of the probable direction of the wind. Such warnings are sometimes sent on the receipt of the Norwegian telegrams alone, but generally not until after the receipt of the British telegrams. The storm-warning telegrams are sent off immediately by the telegraph office to the various stations. They are entered at the stations, on forms of which an explanation has been printed, drawing attention to the fact that they are not prophecies, but announcements that there is a storm in the neighbourhood, of the approach of which to the place there is some reason to fear. These telegrams are made known by being posted up at the telegraph stations, by messengers to the harbour-masters and pilots, and during the great fisheries messages are sent to the Inspectors of Fisheries, and those functionaries distribute the information. At the semaphore station, Oxö, we have storm-warning signals like the British ones which give notice for north and south storms. At Stavanger the harbour-master has arranged a warning apparatus with balls on a mast. The afternoon telegrams but seldom give rise to storm warnings, owing to their lateness. As a rule, storm warnings are only sent to southern Norway. The want of telegraphic information from the Färoes and Iceland forbids us issuing storm warnings with any pretence to certainty for northern Norway.

It is only in this year that messages from the Swedish stations have arrived, and we cannot yet see what the result of the activity of this system will be in the development here referred to. It is only for the year 1870 that we have complete statistics on the proportion between storms which have arrived, and which were warned before, since the Danish stations did not send telegrams in former times. In this year 18 per cent. of the storms which took place in southern Norway were warned for, and for the towns the number was 33 per cent. All warnings were accompanied by storms. In the last years storm warnings have been oftener sent out than formerly. The experience which we have of the proportion of the warnings to the storms which follow may be collected in the following principles.

A not inconsiderable proportion of the storms which have struck southern Norway have arrived without warning. The reason is to be found in the imperfection of the theory, in combination with the deficiency of telegrams and the insufficiency of the staff for constant watching of the weather. Changes in the atmosphere often take place so rapidly, that from the situation of one morning we have not been able to foretell a storm for the next day. I can give many instances of this. Storm centres come from the north-west without affecting the barometer at Thurso (N.W. storms on the west coast and in southern Norway); storm centres coming from the Arctic Sea, over the Gulf of Bothnia (high north winds in the easterly part of the country); an increase of the gradient owing to the fact that pressure falls in the adjacent countries, while it rises in Norway at the same time.

Storms of which we give warning from Christiania at noon, and which in the morning had not reached the towns on the coast, are according to the observations already quite developed in the morning at the lighthouse stations. Such warnings come too late. Too long a time elapses between the issue of the telegrams in the morning from stations, and the return of the storm-warning telegrams from Christiania to the same places.

The storms which we are so fortunate as to be able to warn in time are those belonging to the barometrical minima, which in the morning are fully developed over the British Islands, *e.g.*, over Ireland and the Hebrides, or storms from the north-west, which belong to the rear of the minima which have shown themselves in the morning by low pressure over southern Norway.

The storms of which warning can be issued are those which belong to a barometrical minimum. But at the same time there are cases in which we cannot issue warnings of storms for the coast of southern Norway, although reasonably deep barometrical minima show themselves over the British islands, *e.g.* when the cold in Norway is permanent and severe. The best sign of this we have in the relation of the temperature at Dovre, at a height of about 2,000 feet above the sea. When a southerly wind has commenced and temperature is rising, this condition shows itself in winter a day or two sooner at Dovre than at Christiania. In this case we may assume that a barometrical minimum will pass over the country. But if the cold is severe and permanent, barometrical minima pass either to the south of Norway, whose southern coasts feel winds the force of which is scarcely that of a storm, or else pass outside the west coast to the Arctic Sea.

For the storms which are developed on the border between barometrical minima and maxima, where the gradients at times reach to a considerable height, owing to the fact that the pressure falls in the minima and rises in the maxima, we can issue no warning, because the amount of the variation of pressure at different stations is comparatively small, and we have no knowledge of the conditions of the simultaneous appearances of these phenomena.

The addition of the Swedish and Danish stations to our storm-warning system must decidedly give much greater certainty than previously to our warnings, and must put us in a position to be able to warn for more storms than heretofore. This is especially the case with storms which belong to barometrical minima and which move down over the Gulf of Bothnia, and storms whose centres pass to the south of Norway. In the last respect, as in general, daily telegraphic reports from North Germany would be of importance.

With all its imperfections, I think that our storm-warning system is of some use for our population and our coasting navigation. It must be admitted that the persons to whom the warnings are directed are too little inclined to use them as warnings in accordance with their instructions, but they demand decided prophecies, and it certainly happens that warnings which in some places are accompanied by a storm, in other places are only accompanied by winds of moderate force, or that the warning comes too late, all of which facts weaken the confidence of the general public in the warnings. But both the Inspector General of Fisheries and the most highly educated steamer captains bear witness that the warnings are not without their importance for the trade on the coast. Those who criticise the warnings from a one-sided point of view are many, for nothing is easier than to do this, but those who derive benefit from them are not nearly so ready to bring this to the knowledge of the public, for when the danger is over everything seems to have gone as it ought to have, and a public statement of this never occurs to these people.

If we could only imagine accurate statistics of casualties at sea which might be avoided by timely warnings. On the other hand, statistics of the property saved by good warnings is a thing which cannot be thought of. The position of us who issue warnings is certainly not favourable. The malcontents are many and speak loudly; the contents are few and are silent, and the competent judges are perhaps even fewer. And yet the salvation of a single ship is worth a great deal more than the expense of the storm-warning system.

I am therefore of opinion that storm-warning systems should continue their activity, and I have long been occupied with plans with the object of giving the system a wider activity. Neglecting, for the present, the development of the theory, and the addition of several foreign stations to each system of observation, I think that useful results might be obtained by the following rules :—

The central office for the issue of storm warnings should be at some place on the west coast. As the conditions now are, the morning telegrams must first pass over the lines from the west coast to Christiania, and then, after the telegrams have been here discussed, storm-warning telegrams must pass over the same lines to the coast.

It is true that electricity passes along the lines with a velocity which leaves nothing to be wished, but the sending in and the receipt of the telegrams, and the delay of them for the time which suits private correspondence, causes a retardation which sometimes extends to some hours. By this means valuable time is lost in many cases. If the storm-signal office lay on the west coast it could get the Norwegian, Swedish, and Danish telegrams just as easily as we now do at Christiania, but would get the British telegrams, which are of superior importance for us, much sooner, and besides, the falls of barometer and other signs which precede most of our storms would be shown by the instruments at the stations themselves, several hours before they appeared in Christiania, and so would be under observation during the whole day. On the coast the observations of the appearance of the sky and the state of the sea, and, in short, all the weather signs of the practical experience of the fisherman and sailor, would be placed at the service of the issuer of storm warnings, and when by means of this the news of a storm which approaches from the west, the direction from which most storms come, would be brought to the knowledge of the office much earlier and with much more certainty.

But this is not all; the district of coast which is mostly threatened is that where the office is placed, and the warnings would reach most quickly and easily and without any circuit the actual places which want them first I think such a storm-signal office should be a filial office to the Meteorological Institute, which ought to have its site, like a scientific establishment, in the University of Christiania.

At the same time when the certainty of the warnings might be improved, we might consider a more simple notification of the same to the public. This might easily be effected, if at all the places to which the warnings are sent in general, signal apparatus were established which, by simple signals, would announce the meaning of the contents of the warning. These apparatus must have attendants who would always be ready to hoist the signal immediately after the receipt of the warning at the station. They must be erected at prominent places, and must give signals so perfectly that fishermen and sailors should not be compelled to land in order to gain further information.

The QUESTIONS proposed by the SUB-COMMITTEE have been answered in the main in the preceding lines. For the sake of completeness I add the following remarks :—

Question I. See pages 38 & 40.

Question II. "Gradient" is a difficult conception for the majority of people who use storm warnings. These people want to know how the wind will blow, and leave the studies and calculations of it to meteorologists. However, I refer to pages 36 & 39, and to my Storm Atlas, p. 5. The gradient, according to my idea, gives the actual wind, and gives no warning for a future wind.

Question III. See my Storm Atlas, and page above.

Question IV. See page 39 above.

Question V. See pp. 38 & 40 above. The announcements by meteorological telegrams are now a necessity for trade, shipping, and sailors. The time is not yet come when such people will know so much of meteorology that they themselves can draw conclusions from the telegrams. This they leave, in accordance with the principle of the division of labour, to meteorologists.

On storm signals, see pp. 40 & 41 above. If we wish to organize storm signals which should only give an announcement that there is more precise news, I fear that sailors would make but very little use of it. A complete signal would, in many cases, economise valuable time which it would take if you were to seek the complete news ashore before you could make the necessary preparation against the storm.

Question VI. Many semaphores have already got storm-signal apparatus. The international code of signals contains the necessary information for a meteorological correspondence between ships and a semaphore.

Dr. A. v. Oettingen, University, Dorpat.

To II. Yes. (C.) recommends itself as the best, because the errors of the instruments are almost entirely eliminated. In principle, however, (B.) and (C.) are almost identical, for in both cases there exists the fallacious hypothesis that at sea level in all latitudes, the same annual mean pressure prevails. The actually existing difference (Spain 763, Ireland 757, mm.) should not be eliminated. If the barometric mean for a district is known, reductions to this mean should be made, and after carrying out this reduction the deviations can always be found. However, in great continental districts this reduction seems scarcely practicable; therefore (C.)

To III., as far as storm signals, not at all.

To IV. Barometer (better, deviation of barometer from annual mean). Thermometer (*not* deviation). Wind, with attention to force, and accurately. Direction. Cloud and precipitation. Besides these elements, much might be expected from—1st, the change of the barometer in the last 2, 3, or at most 8 hours. 2nd, the variation of the wind in the last 2, 3, or at most 8 hours.

In order to render the latter possible, there must be in existence accurate wind observations and wind integrals. Science will not in general attain to such values until it gives up the notation of winds in groups as its chief object. It would be best for prognosis to give the exact wind integral of the last hour of the last but one (both according to components).

To V. Facts. Prognosis is often very possible, especially when the atmosphere is disturbed, and it may be assisted by communications of the variations. If the intelligence is not renewed every 8 hours, as in the case in America, subordinate stations should give, as well as the facts, the variation from the observations taken 8 hours previously. Chief stations, the variation values for shorter periods.

To VI. To the wish urged by competent sailors, to have intelligence of facts, I can agree. Owing to want of experience I do not venture any proposal, but indicate a plan which may possibly be carried out. Could not 100 or 1,000 weather charts for pressure and wind be drawn and published? Each chart should have a number. The number should be hoisted which corresponds to a chart which almost exactly represents the prevailing weather conditions. Each ship should have such an atlas. No semaphores could possibly give a representation approximately correct, and at the same time intelligible. Practical experience will soon teach us what the extent of the area covered by the chart should be. We might also deduce maxims as to the degree to which the typical chart might differ from the reality.

Professor M. A. F. Prestel, Emden. Extract from his pamphlet entitled "Ergebnisse der Beobachtungen und Erfahrungen betreffend die Sturmwarnungen und Sturmsignale." Emden, July 1873.

I.

The practical value of the storm signals at present in use is clearly shown by the circumstance that that portion of the population which is immediately concerned with navigation is constantly demanding the establishment and extension of storm warnings and storm signals. Their practical value, however, depends absolutely on the degree of confidence which can be placed on the warnings emanating from the central meteorological offices.

II.

My experience of storms since 1860, shows me that it is clearly necessary to add the barometical gradient to the notices of the direction and force of the wind.

The mere differences (A.) between the barometrical readings at the several stations (even when reduced to 32°) are *not* sufficient for the objects of storm and weather prognosis. When the air is at rest or in equilibrium over a considerable portion of the earth's surface, the mathematical formula for the reduction of the barometer to sea level gives quite satisfactory results; but when the air is disturbed by a storm the final result given by that formula, and with it the barometrical gradient, is uncertain to the extent of several millimètres. On the other hand, the deviations from the observed barometer readings from the averages (C.) afford the necessary information even for the object of storm warnings.

III.

It is not only the reading of the barometer, but also the readings and changes of the thermometer, the hygrometer, and other meteorological instruments must be carefully observed.

IV.

Telegraphic weather reports, to be of use for the object of storm prognosis, must be quickly brought to the knowledge of those interested therein, and must therefore be as brief as possible. The observations contained in the telegraphic weather reports are sufficient for storm prognosis, but must be regarded as the *minimum* of what is required to enable anyone to predict storms.

V.

The physical laws which govern the changes in the atmosphere are not as yet known well enough to allow of our determining beforehand the path which a storm will take which arises anywhere on the earth's surface. On this account the definite predictions of storms are often astray.

The uncertainty as to the track which the storm will take would be entirely removed if the observer had a sufficiently extensive knowledge of the condition of the atmosphere in his neighbourhood, and on this subject the telegraphic weather reports ought to afford him information. If these cannot be communicated quickly enough to him in their entirety, there is nothing left but to communicate to him in as simple a manner as possible the most important general features of the condition of the atmosphere by means of *signals* which shall be visible at a reasonable distance. The methods of effecting this object introduced on the coast of Holland since 1860 by Professor Buys Ballot have proved themselves to be thoroughly satisfactory.

VI.

It is extremely difficult to convey the conditions of weather to vessels at sea off the coast by means of semaphores or signals from lighthouses, owing to the comparatively slight distance to which they can be seen. On the other hand, the "storm warner" which I have constructed places the sailor in the position of being able at once to form conclusions on all the indications in respect of wind, storm, and weather, which may have practical interest for him, without any other information.

Rev. Francis Redford, M.A., F.R.S.E., &c., Silloth.

I.

In my opinion the system of storm signals and warnings at present in use in this country, combined with the "Daily Weather Report," is most efficient and invaluable; this opinion is founded upon a careful attention to, and co-operation with, the system from its first commencement.

It rarely occurs now that an atmospheric disturbance visits this coast (the north-west of England) without a warning being previously received. I think also that the general warning now given is preferable to the practice of former days, when the probable course of the gale was indicated by the hoisting of a cone above or below the signal drum.

I do not see the French Bulletin with any regularity, and cannot therefore judge of the aid it affords in this particular; but the English Daily Weather Report, with the accompanying charts, leave nothing to be desired, unless it be the addition of a new station on the north-west coast of Ireland, say on the Island of Aranmore, off the coast of Donegal, or at Rossan Point; reports from either of these places would be of more service to the west of Scotland and the north-west of England than those from Greencastle and Donaghadee.

II.

Unless the barometric gradients are given, no proximate computation can be made of the force of the approaching gale.

The gradients should have references to the actual readings, at two stations at least, to windward of the station warned, the readings of course being corrected and reduced.

III.

It is essential that temperature and the hygrometrical condition of the atmosphere should be taken into consideration in communicating information for storm warnings. On this coast a gale from the S.W. is almost invariably preceded by an increase of temperature and humidity, bearing some proportion to the force of the gale. The contrary is observed, but not in so marked a degree, when a gale is approaching from the N.E.

IV.

The readings of the barometer and dry and wet bulb thermometers, with direction and force of wind, should be the minimum; nothing less than this would be of any practical value.

V.

A simple telegraphic communication of facts is all that is necessary (and perhaps all that we are justified in giving), including the conditions of the atmosphere in as wide a range as is practicable. The public announcement to be made as at present, by the hoisting of a signal in a prominent position, and posting up the detailed information.

VI.

After much consideration, I cannot see in what way intelligence of dangerous winds can be conveyed from the shore to ships at sea, in time to be of any essential service to them; the atmosphere is so generally hazy at such times, that a ship might strike upon a lee shore before a semaphore, or other signal, could be seen.

Capt. Rikatcheff, Central Physical Observatory, St. Petersburg.

I.

The system of storm signals now in use is useful for practice, but this conclusion is based only on my own estimations, after having read English, French, and American bulletins, without any calculation. I think for the exact solution of this question it is necessary to make a report similar to that made by a Commission of the British Government on the same question in the year 1866, that is, to calculate the per-centage of successful and unsuccessful warnings.

II.

Yes, certainly. The gradients of barometer must be given, referred to 760 mm. at sea level. Without reduction to sea level the barometer readings at different stations are not comparable. The reduction to the normal height of the stations does not give the idea of the actual distribution of pressure. The normal distribution of the pressure is approximately known for a great part over the globe, and must be determined where it is not. Then every normal or mean reading of a barometer at any station can be adapted as corresponding to the normal pressure at sea level taken from the isobar chart, and it will be easy to reduce every reading of the barometer to the sea level, as good as to the normal reading of the barometer. As an illustration of my idea, I will give an example :—At the parallels of 30° over the ocean the mean pressure is higher than at the equator, and the wind is blowing from the parallels to the equator. If in any given day the distribution of pressure is normal, on a chart with isobars giving the absolute value of the barometer reduced to sea level (or referred to 760 mm. at sea level), it would be at once seen the dependence of the wind from the pressure; but with the system of reducing barometer readings to the normal of the stations you will have on the same day the deviation O at all stations, and you could not trace isobar lines at all.

III.

Temperature, vapour, clouds, and especially rain, can be taken into consideration, respectively, to the probable diminution of the pressure on the locality.

IV.

Once a day wind, direction, and force, barometer, temperature, amount of cloud, and remarks about rain, snow, &c., from all stations, and another (second) telegram from a few stations in the evening.

V.

I think the best means to answer this question would be to prepare a large and detailed atlas of meteorological charts for any year; the state of weather should be traced at least at three different hours every day, and if possible every two or three hours. On each chart should be given as many observations as possible, and the exact isobars and isotherms traced. Then it is possible to try to forecast from preceding charts the state of weather in next six or eight hours only, and compare the forecast with the state of weather. If this will not be successful it will prove that it is quite impossible at present to forecast weather a day before, and on basis of very incomplete observations, which are transmitted by telegrams. The communication of the state of weather in adjacent localities with warning every time when it is a disturbance in the atmosphere should be, I think, the best method till a more exact method for forecasting weather will not be found; and this could be done by means of detailed discussion of observations for past years as mentioned. My answer to the second part of the question V. is Yes. The captain being informed that the general state of the weather, is doubtful, can send for detailed information to the stations, or ask them by signal.

VI.

The signals could be, I think, transmitted by means of lighthouses.

Professor R. Rubenson, Central Meteorological Institute, Stockholm.

Although my own experience in respect of the questions contained in your letter of April 30 is very small, owing to the fact that the telegraphic system in this country has only commenced operations since the 1st of May 1873, so that I am not in a position to answer these questions in detail, I shall state, in the interest of the subject, the method of procedure as regards the incoming telegrams in this country. The number of places whence we receive daily reports by telegraph is 22; of these nine are in our own country, four in Norway, two in Denmark, three in England, and four in Russia; among these the Paris telegram and that from Sumburgh Head are not counted. The Central Institute is connected with the telegraph office by a private wire, and the despatches are sent on by that. This transmission commences at 10.30 a.m. and the above-mentioned messages, both home and foreign, usually arrive here by 12.30. In the meantime all the reports as they arrive are entered in a bulletin which is intended to be put up for inspection in some frequented places in the city. Besides the principal meteorological elements, such as the barometer (m.m.), thermometer (C.) wind direction and force (scale of six), and appearance of the sky (in words), this bulletin contains also a short summary of the weather in northern Europe. In order to give this summary a concise form, and to ensure that it shall only give the characteristic indications of the prevalent weather, a synoptic chart is drawn in the first instance, and the most prominent phenomena on this chart are briefly described. The summary is to a certain extent couched so that the numerical sata may be dispensed with. It is furthermore destined to be telegraphed to such ports as have subscribed to the telegraph office for its transmission.

As a specimen of the form which is taken by this summary, I give that of the 6th instant (June), which runs thus:—

"In the south and centre of Sweden bright weather with light variable winds, and a gradual slow fall of the barometer. On the west coast of Norway strong winds from W. or N.W. with a very low temperature. The barometer is falling more rapidly in the north of Scandinavia, but, on the other hand, is rising over England and the North Sea."

At the end of the bulletin the observations taken thrice a day at Stockholm are inserted.

This bulletin is not only posted up at certain places in the town, but is sent to the evening papers, which publish the contents in full. As I have said above it is only the so-called summary which is sent to the seaports by telegraph. We have not yet issued actual storm warnings, but I have the intention of only indicating in advance in this summary the most serious storms. As soon as this, as may be hoped, can be carried out with certainty, I think that it will be time to provide some stations with storm signals, but for the present I think that this step would be unadvisable. As you see our efforts are directed chiefly to the attainment of experience as to the possibility of issuing trustworthy storm warnings. For the present this portion of our future activity has not yet been called into existence.

W. W. Rundell, Underwriters' Association, Liverpool.

I.

English storm warnings appear to have worked satisfactorily so far as my experience in Liverpool extends. There seems no practical mode of extending their use available, except by indicating in some way the direction and force of the existing storm or disturbance. No good mode of doing this appears to have yet been devised. The mode tried here two or three years since (invented I think by Captain Toynbee) required to be seen from a particular direction. A signal or signals which could be read equally well from any direction would be desirable.

II.

I do not think this information can be given in a way to be generally useful to the public. Notice of a difference equal to a certain amount occurring within two or three hours is of importance to a director, and the director for each country might be left to define the amount which he considered to be important.

III.

It seems right that any unusual change of temperature should be telegraphed in the same way as any unusual change of pressure. It appears pretty certain that changes of temperature sometimes show themselves in advance of the coming change of pressure.

IV.

One telegram per day giving actual observations at specified times and at specified stations appears to me the maximum should be expected.

V.

The telegrams should, as a rule, be confined to the record of facts. Mode of publication of the facts to be left to the director for each country.

VI.

I do not think the time has yet arrived when this can be done with advantage. The signal referred to, in answer to question 1, and the hour to which the observation refers, will both be required.

Dr. Guido Schenzl, Royal Hungarian Central Meteorological Institute, Pesth.

Pesth, May 20, 1873,

I FORWARD herewith my individual opinion on the questions submitted to me, and permit myself to add the following remarks:—

As I myself have never stayed long in a seaport, I have thought it advisable to submit your questions and my views on them to M. H. v. Littrow, Royal Marine Inspector of Hungary, and M. Emil Stahlberger, Hydrographer, Fiume, and they have been so kind as to send me their opinions, which in some respects differ from my own.

I believe that M. v. Littrow will himself attend the Congress and explain his views in detail.

The meteorological communications for shipping should be confined to a minimum. The semaphores, by means of optical telegraphs, are in a position to give the necessary signals, which consist simply of an indication of the threatened storms according to the four cardinal points. At most it might be indicated by a flash at the intermediate stations, such as between the Adriatic and Mediterranean, to which sea the signal referred.

If at the semaphore stations warnings for both seas have been received, the two signals should be hoisted successively when a ship comes in sight. M. v. Littrow is further of opinion that, for the present generation of sailors, M. Buys Ballot's proposal is too advanced, and it does no one any harm if for once a threatened storm does not come on. Still he would admit Buys Ballot's system for local signals in harbours for ships going to sea. In other respects M. v. Littrow agrees with me.

The views of Professor Stahlberger are in the main as follows:—

As I do, he draws a distinction between two courses. The one, the communication of the conditions of weather to the port itself and its immediate neighbourhood, the other the storm warnings. For the former he wishes for no signals. The information should be posted up on a black board at the harbour or marine offices, and should be for the last three days, for the information of captains outward bound.

With respect to storm signals (these should be given, and not mere elements of the meteorological conditions). It is not sufficient merely to hoist the warning signals, but an explanation should be kept in every harbour office. If the storm should not arrive at the station named it should be stated where it has gone, so discredit to the system would be avoided.

M. Stahlberger is also of opinion that the captains (N.B., he has the circumstances of the "Quarnero" in his mind) have had too little meteorological education to derive any benefit from information of depressions, maxima, or gradients, or in fact from figures at all. Especially, under the circumstances, the meaning of this data for different coasts, according to the character of the coast itself, must differ, and we could not therefore expect that sailors would always be able to apply the right interpretation to them. This must be left to professional meteorologists, and they give enough assistance when they indicate from what quarters a storm may be expected.

The signals should be kept as short and as generally intelligible as possible. The reports at the lighthouses should, however, be reasonably full. The increased cost of telegraphy induced thereby would be partly to be paid by the Ministry of Commerce.

Of the greatest importance are warning signals for local storms. The Meteorological Congress should aim that where local storms occur, but the indications of them are not perfectly clear, the investigations with regard to them should be taken up with as much energy as possible. The especial application of these remarks is to the Bora in Fiume, which according to the data at Fiume cannot be foretold. We only know that it is generally after a Scirocco. Accurate information on it, local observations from the mountainous country behind, must teach us, and these observations be carried on with energy. Only those observations must be united by telegraphy with the Marine Office at Fiume.

1. On the action of storm signals which have been hitherto in use I have no special experience; but I believe that after consideration, that ever since a short time after their establishment these arrangements have proved themselves useful for navigation, and will become more so in proportion as they are perfected, especially for harbours, and such a position of configuration of coast of that of Fiume.

In the meantime I agree with the opinion of M. Buys Ballot, that in the present condition of meteorology it is not actual storm signals, which by their uncertainty might easily shake the confidence of sailors, but that much more the meteorological conditions, the maximum of pressure, should be regularly signalled to them, and that the application of this information should be left to the sailors. An exception to this should be the local storms, as for instance the Bora.

2. Besides giving the actual wind in direction and force, the gradient of the barometer should be announced, somewhat in the same way as is done in Utrecht, by a movable arm whose inclination shows the extent of the depression.

In the regular weather signals gradients should be calculated according to the deviation from the normal readings. This might also be the case for the warning signals of storms of a more local nature.

3. Temperature and humidity, especially the former, should in my opinion not be disregarded in the telegrams sent to the harbour offices, as especially the origin of local storms, and of the different whirlwinds, will thus be, in many cases, indicated; viz., attention to the conditions of temperature will be of great importance where the sea-coast is separated from the mainland by high chains of mountains. And in temperature it seems most valuable, instead of giving the absolute reading, to give the deviation from the normal indications, where the latter is known. As to more than humidity, it appears to me that the occurrence of strong precipitation is deserving of attention, and its communication to the coast stations would be valuable. To adopt them into the meteorological signals for the coast would hardly seem to be desirable, as by such means the signals would be far too complicated.

4. In accordance with what has been said the minimum to be indicated will be :—

Barometer and thermometer—deviation from the normal; wind direction and force; precipitation and other special phenomena. It is hardly necessary to say that these should not be sent on any definite hour, but should be communicated as soon as possible after they take place.

5. It is only actually existing conditions of the atmosphere which should be signalled regularly, and it is only in storms which appear locally that actual warnings should be given at the place, when we have sufficiently certain signs of its approach.

I consider the establishment of signal apparatus useful, especially in such places where the vicinity and the elevation of the coast usually prevent the sailor from seeing the usual signs of weather.

6. As I know too little about the details of the arrangements of lighthouses, I refer myself to the opinion of Marine Inspector M. H. v. Littrow, with the addition that no regular storm warnings would be considered useful unless there should be night signals as well as day ones.

Scottish Meteorological Society, Edinburgh.

I.

The practical utility of the systems of storm warnings hitherto in use in the United States, in England, and in France, has been very considerable. The utility of storm warnings would be further increased—

(1.) If additional telegraphic reporting stations continue to be added to westward, as regards the United States over the region to west of Mississippi, and as regards western Europe, in north-west of Ireland, in north of Shetland, in Farö, in Iceland, and in Norway north of Christiansund.

(2.) If a constant watch were kept as regards Great Britain, say at three stations, Stornoway (or St. Kilda if possible), Valencia, and Corunna, whence telegraphic despatches could be sent to the central office in London immediately on the premonitions of a storm appearing, and power were given to the telegraphic wires to collect information bearing on the approach of the storm.

(3.) If the records of past storms which advanced on north-western Europe from the Atlantic were discussed, particularly over that part of their course shortly before they reached the west of Europe; and the weather of the British Isles discussed at the same dates, with the view of ascertaining more exactly the earliest premonitions of future storms. which can be detected from the observations made on land alone.

II.

In addition to the direction and force of the wind which is actually blowing, the barometric gradients should be stated in order to give warnings of approaching wind. These gradients should be referred to the differences between the readings at the different stations, reduced to 32° and sea level. With reference to this point, however, it is necessary to fix on some height above which it is not expedient to reduce the barometric observations to sea level. At stations of great height it is better to refer the actual readings to the normal heights of the barometers at the stations, and to compare the results with the deviations from their normals at stations at lower levels.

In cases where observations from two or more high stations are available, the barometers should be reduced to the same level, say the height of one of them.

There is a fatal objection to referring the gradients to the mean normal heights of the barometer at the stations, viz., that this method does not represent the actual atmospheric disturbance, owing to the great difference which obtains between the normals of different places when these are reduced to sea level: thus the January normal for Stykkisholm, Iceland, is 29·333 inches, for Thorshavn, Farö, 29·500 inches, for Sandwick, Orkney, 29·627 inches, for Stonyhurst, Lancashire, 29·818 inches, for London, 29·947 inches, and Gibraltar, 30·138 inches. Hence, suppose that on a particular day in January the barometer stood at these places as above, if we were to refer the gradients to the normals, no disturbance would be indicated, whereas there would be considerable disturbance in the pressure of western Europe, amounting to 0·805 inch from Gibraltar to Iceland. There is another objection to the method of referring the gradients to the normals, viz., the difficulty of obtaining the requisite number of good comparable normals. The method might, however, be temporarily employed in countries of limited extent where the normals of the stations reduced to sea level vary little from each other, and where the errors of the barometers and their heights above the sea are not known; but it is not to be recommended for adoption in any general system of weather telegraphy.

III.

The observations of temperature, vapour, &c., may be immediately utilized as indicators of the character of the air-currents concerned in the atmospheric disturbance, that is, whether these are equatorial or polar. Further and more exact inquiries into the relations of temperature and vapour to atmospheric disturbance are urgently called for, in order that these observations may be utilized to the utmost in their bearing on storm warnings. In this connexion observations at very elevated stations are of great value, becauses changes frequently take place sooner at these heights than at lower levels. For example, changes of weather (wind, temperature, vapour, &c.,) have been observed to occur 36 hours earlier at this society's station at Wanlockhead, 1,334 feet high, than at Drumlanrig, 10 miles distant, but only 169 feet above the level of the sea.

IV

Since the director in the British Isles might be content with one telegraphic station in Belgium and Holland respectively, whereas the directors in these countries would require several British telegraphic stations for the proper working of their system of weather telegraphy, and since, on the other hand, the director of the British Isles might require observations from as many telegraphic stations in France, Sweden, and Russia, as the directors of these countries might be content to receive from him, it is evident that the exchanges between different countries can only be a matter of mutual arrangement.

V.

The present position of our weather knowledge does not justify us in issuing distinct *prophecies* of coming weather.

Our knowledge of weather is, however, amply sufficient to justify the issuing of "forecasts" of weather, it being distinctly understood that these "forecasts" are to be accepted only as *cautionary* signals of a storm of wind which will probably strike the place at which they are hoisted. In addition to this, the Council are strongly of opinion that signals should now be introduced indicating the *direction* of the storm of wind which is expected.

Directors in charge of weather telegraphy ought not to limit themselves to issuing indications of the condition of the atmosphere in adjacent countries, leaving the public to draw their own conclusions therefrom, but should take the responsibility of giving the public the benefit of the conclusions which they, as skilled meteorologists, have formed, as to whether they think the storm will strike any part of the district under their charge.

In addition to the usual signals indicating a coming storm and its direction, such instruments as Dr. Buys Ballot's aeroclinoscope might with advantage be added, if it be convenient to do so.

In these remarks regarding the practicability of storm warnings, the Council desire it to be understood that they confine themselves to the United States and to western and north-western Europe. As regards the regions of central Europe such as Saxony, Austria, &c., where it is not so much storms of wind as storms of hail and rain, of which the public are most interested in being forewarned, and as regards the countries bordering on the Mediterranean, the Council are not in a position to express an opinion as to how far systems of signalling coming weather which would meet the requirements of these countries is yet practicable.

The Council would, however, state their opinion that in the discussion of the practicability and utility of storm signals by the Meteorological Congress at Vienna, the question ought to be considered under three heads, kept separate and distinct from each other, viz. :—

(1.) As regards western and north-western Europe.
(2.) As regards countries on Mediterranean; and,
(3.) As regards central Europe.

And that the Congress should resolve on each head by itself, and exclusive of the other two heads.

R. Strachan, F.M.S., Meteorological Office, London.

I.

I am of opinion that no system of storm signals has been, or is at present so good or so useful as the one originated and practised by Admiral FitzRoy; but I think that his five signals were redundant and might be conveniently reduced to two, namely, "*cone point up*" for gales expected to blow from any direction in the semicircle N.W. by E. to S.E., and "*cone point down*" for gales expected from the S.E. by W. to N.W. points of the horizon. I am also of opinion that the period of three days, for which he kept the signals hoisted, was too long, and that two days would be long enough. His system was premonitory and inseparable from his method of forecasting weather (*vide* Report to Parliament, year 1862, page 4) which was based on the laws of wind in relation to the distribution of barometric pressure.

The systems of the United States and of France are also inseparable from the practice of forecasting weather; but the modes of making the signals public are not, in my opinion, so effective as Admiral FitzRoy's plan.

The present English system of signalling by "drum" "existing atmospheric disturbance" does not rest upon forecast, is therefore not amenable to success or failure, and apart from the despatch or message, the signal by itself is of too indefinite a meaning to merit much attention. It always requires interpretation, which is difficult to get, unless conveniently near where the message is posted up. The drum is now kept up 48 hours from the time of receipt of the order to hoist it, but since the message does not arrive at all the ports at the same time, it would be more uniform and consistent to reckon from the time of transmission.

II.

My answer to *A.* is Yes; and to *B.* and *C.* No. The seafaring community, in common with the general public, will not trouble themselves about the technical interpretation of gradients, however expressed. Meteorologists should use the term gradient to express the actual difference of pressure at sea-level between two stations, because the winds are related to the actual distribution of atmospheric pressure. Neither an assumed pressure of 30 inches at the sea level, nor normal heights of the barometer, has anything to do with the relation of the dynamics of the air to its statical pressure.

M. Buys Ballot, who is accredited with the generalization of the law of storms to all winds, arrived at this important result by an imperfect induction, for he used normal values of the barometer. Had it not been that his stations were at short distances apart, and consequently that their barometric normals differed inappreciably, he would have arrived at a false conclusion. Mr. F. Galton, in "*Meteorographica*" used the proper method of isobars, and enunciated in explicit terms the law of wind in relation to statical pressure. As he does not quote Buys Ballot, it is to be inferred that he was the first to prove this fundamental law upon correct principles.

III.

Temperature, in reference to its normal value for the date, should be taken into consideration in forecasting weather, as should also rain, vapour, &c. But when you ask how this should be done, you ask for a prize essay, since the matter is not sufficiently matured to be treated in an off-hand manner. Such meteorological elements should yield information of value to agriculturists rather than to mariners.

IV.

A concise statement of wind and weather, the steepest gradient existing in the district at the time, and the rate of rise or fall of the barometers at each end of the gradient constitute a serviceable amount of information from one country to another, on the subject of existing weather.

V.

I am of opinion that the centralisation of telegraphic weather reports affords a sufficient basis of facts for making weather forecasts, and therefore that they should be published. Why should the public be expected to expend time and thought individually in doing what one or two experts should be so much better able to accomplish for a large portion, if not the whole of the nation? This to my mind is really a question of economy in the expenditure of brain work. I also think that the forecasts should be made once a day, or oftener, but to apply to two clear days in advance; the days always to count say from 9h. a.m. to 9h. a.m. They should be made public as expeditiously and widely as possible, by methods analogous to those employed in the United States.

The rate of rise or fall of barometers should be reported to the central office, by taking a reading one hour before making up the report. In the absence of this information, forecasts could be made by estimating rates for the rise or fall of barometers, or by assigning limiting angles for veering of winds during 48 hours.

At present the English practice is to give synopses from the particular observations, which are valuable because readily understood by the generality of people, who do not care to consult the tables.

The United States publish probabilities as well as synopses. The importance attached to these probabilities by the public immensely outweighs the attention given to the synopses. The reason is obvious; they are more concerned about coming weather in the operations of practical life than with that which has passed.

The information received from other countries should be given in the synopses, and taken into account in estimating the probabilities.

It has been asserted that good tide gauges give indications of changes of atmospheric pressure before the barometer. This subject ought to receive attention from official meteorologists. They might thereby be enabled to give warnings of unusual tides in time to take precautions to meet them, while the earlier premonition of storms would be of value.

VI.

A short series of letter combinations might be assigned in the commercial code for interpreting the shore storm signals, by using two or three flags. Lighthouses, and ships leaving port, should be required to keep these flags hoisted until nightfall of the day on which the shore signal is seen.

G. J. Symons, Camden Square, London.

I.

Satisfactory. Should be continued and developed. So far as I know I believe there is insufficient frequency of communication in most countries. I consider that the central office should never be left day or night without a responsible officer in charge, that the omission of Sunday telegrams is inconsistent with the importance of the object, and that either by a system of pecuniary rewards or otherwise, the personal interest of the observers should be cultivated. That every effort should be made to induce Government to carry the telegraphic lines to the extreme points of land, *e.g.*, the British Government to Broadhaven and St. Kilda; the Danish to the Faroe Isles and Iceland; the Norwegian to Hammerfest. I also think that it is impossible to spend too much time and thought over the discussion of past as a guide to future weather, and that analyses of Atlantic weather like that by Captain Toynbee should be continuous and not occasional.

II.

Yes. I suppose we must accept that given in the British Daily Weather Reports, but I should have preferred to have made the height constant and length variable, *e.g.*, 1 inch per 417 miles, or at any rate 0·24 per 100 miles instead of 0·12 in. per 50 miles.

III.

I do not think we yet know enough on this head to lay down positive rules. Of course both temperature and moisture are guides as to the character of coming weather, but the last clause of the first answer applies most strongly also to this.

IV.

Must vary with geographical position.

V.

I think the directors of meteorological systems should intimate their opinions on the probable sequel to the atmospheric conditions which they announce as existing; doubtless they would be terribly wrong sometimes, but the training would soon give such an insight as to render the forecasts of great value. The experience and ability available at the central office is so evidently superior to that of the recipients of the telegrams which may be issued, that the plan of leaving the recipients to draw their own conclusions seems to me inexpedient.

VI.

I think the signals at every station should be twofold, one to express the opinion entertained at the central office, the other to indicate the actual height of the barometer and the direction of its motion during the previous six or more hours at the outpost. Very complete information as to probable weather might be signalled by a combination of Admiral FitzRoy's drum and cone with Dr. Buys Ballot's aeroclinoscope (which should be so modified that no mistake could be made as to its indication). For indicating barometric readings and changes I know no better principle than that adopted by the late Mr. Smith at Scilly, but it would be improved by the addition of a third pole making the ground plan an equilateral triangle; the indicator should be a frame covered with canvas and with the ends left long, so that they could be pulled out by a rope *upwards* when the barometer was rising, and *downwards* when it was falling. Of course where the signal can only be seen from, say 100°, the simpler arrangement at Scilly is sufficient and cheaper. (Sketches can be supplied if desired.)

Capt. H. Toynbee, Marine Superintendent, Meteorological Office, London.

I.

I think that certain ports should have a notice when the weather is doubtful, and that it would be well to have a signal (say the cone) which merely implies that the sender of the telegram knows facts which would be useful to all seamen, and that if they wish to know them they must go to the station and read the telegram. The drum might be kept for more decidedly bad weather.

II.

I think that a few actual barometer readings should be given, such as show the most important gradients at the time, *i.e.*, I prefer what you distinguish by the letter A.

III.

I suppose the direction of wind ought to be considered in connexion with temperature and vapour.

If the present method of calculating vapour tension be considered satisfactory, then it would be well to calculate it for the different winds experienced in each month; if *not*, the mean difference of the thermometers for each wind should be given with the mean temperature.

IV.

A question which can best be answered by directors of offices.

V.

I think there are cases in which the state of wind and weather at western stations, taken in conjunction with the disposition of pressure at the time, would justify forecasts, and that they should be issued from the head office, as the knowledge required to enable the navigator to apply the facts usefully cannot be at present possessed by coaster and fisherman, who are the most likely to derive benefit from such forecasts. In fact most commanders of large seagoing ships have not the requisite information.

VI.

Both semaphores and signals from lighthouses might be employed. I am still of opinion that it would be well to have two semaphores at each of our important ports, such as London, Liverpool, Newcastle, the Downs, &c. &c., and that as soon as possible each morning they should be set to show the 8 a.m. winds of certain places of importance to those ports. After the weather telegrams have been digested at the head office, the semaphores should, if the director thought it requisite, be reset, by telegraphic communication from that office, and be made to show gales, or other facts of more information to the said port.

G. V. Vernon, F.R.A.S., Old Trafford, Manchester.

I.

As regards this first point further information is desirable; our bulletins here might safely give us some items of probable weather. As regards the French and American bulletins, copies are not generally distributed here, so that but little chance of comparisons can be made except by a few persons.

II.

As regards the gradients, I think that the normal heights at many stations have not been yet properly determined, and this would make C. difficult to return. A. and B. ought certainly to be given. It would, I think, be very desirable to give differences between extreme northern and southern stations, and the same for widely apart eastern and western stations.

III.

With regard to temperature, the amounts of oscillation during the month give an important datum as regards disturbance. I mean the addition of the successive rises and falls of temperature at any fixed hours. The vapour question at present seems a difficult one, as we know really nothing from observations except at comparatively a few feet from the ground. I think at present that the fullest details should be given of the dry and wet bulb thermometers, so as to furnish data for future use, this question of vapour being only in its youth.

IV.

I do not see that I can give any views upon this point, as it seems that the directors alluded to, if capable, should be the only parties capable of settling this point.

V.

If indications of storms which are probably approaching are to be of any value to the seafaring public, the only notification should be a decided signal to show that a storm is tolerably certain, and if so from what point, if there are sufficient indications to point it out. Any attempt to give merely the conditions prevailing at the various ports will be useless to the maritime class, as it looks like setting them a problem to solve, which to them would be simply an absurdity.

If a storm is probable it should be signalled; the additional data is not of much use, but would be so afterwards if carefully tabulated and printed for examination.

VI.

Telegraphic signals might be of great use at such lighthouses as the Eddystone, if shown so as to be seen by approaching vessels, which of course can have no knowledge of the atmospheric conditions occurring, say over northern

Europe, as their knowledge must naturally be confined to that of the instruments on board their own vessel.

How the signals should be given is a great difficulty, as in many cases they cannot be seen far enough. At lighthouses near extreme points of land, such as Start Point or the Lizard, such information, if signalled efficiently, ought to be valuable.

Professor H. Wild, Central Physical Observatory, St. Petersburg.

I can give only very imperfect replies to the questions of the Sub-Committee on the subject of the practicability and utility of storm warnings, inasmuch as in Russia, up to the present time, no system of weather prognosis and of storm warnings has as yet been organized, and I have therefore no practical experience on the subject. The directors of the respective institutes will be best able to form opinions and furnish reports on the results of the experience gained in other countries.

I.

Storm warnings which are in existence in other countries seem to me to have met with sufficient success to authorize the introduction of corresponding signals in Russia for the Baltic and Black Sea. As soon as the Congress at Vienna shall have settled the various questions, I think of instituting storm warnings on the basis of the telegraphic weather reports already organized in this country.

II.

The gradients, according to Buys Ballot's proposal, should be referred to the deviation from the normal readings.

III.

In the discussions relating to storm signals the deviations of temperature and the absolute humidity are to be considered, but for the signals themselves this may be, at the present time, superfluous.

IV.

This question, as it appears to me, does not admit of a general answer. Different countries and districts will have different requirements in this respect.

V.

In my opinion we cannot presuppose that everyone will have the same knowledge of the laws of storms as can be expected from the offices of the Meteorological Institutes. I therefore give a decided preference to careful storm warnings on the part of the latter, issued with the utmost amount of probability that our knowledge allows, as compared with the bare notification of facts.

VI.

No observation on my part is possible.

Besides the storm warnings on the basis of the telegraphic weather reports, I consider the issue of an autographic bulletin by each central office, with special reference to its own country as a rapid publication for the immediate following up of interesting conditions of weather, as most desirable.

APPENDIX.

Professor Buys Ballot, Utrecht, Director Royal Meteorological Institute, Holland.

I.

The French, English, and American bulletins and charts which have appeared subsequent to my communication to the Royal Academy of Amsterdam in October 1850, have in general confirmed the opinion contained in that paper that the wind will take such a direction in the northern hemisphere as to have on its left hand the place where the barometer stands lowest, and that it will blow harder the greater the difference, but that the E. wind in our latitude will not be so strong as the W., which may become dangerous when the differences between Flushing and Maestricht, on the one hand, and Gröningen and Helder on the other, amounts to 4 mm. or more, and although I have deducted in the year 1860, on theoretical principles, these results, which were at first only statistical, yet I now consider that their practical importance is no longer of such high value.

At that time I thought that ships should not leave port when there was a difference of 4 mm. per 150 kilometres in any direction, and I did not pay enough attention to the loss of time caused thereby, while, moreover, we could not be sure enough that ships which would leave port while the wind would be East could get completely out of the channel before they were driven back by the westerly wind. I think that the sailor himself is the only person who can form a practical opinion on the value of the rules.

My own experience since 1860 is contained in the Dutch Annuaries, in which may be found for every day the direction in which the strongest wind has blown at the hour given, with the preceding difference of simultaneous deviation in magnitude and direction. In Amsterdam Mr. Enslie on every day has given the direction and force of the wind as expected from these conditions of deviation, and from hour to hour the observed direction and force of wind is given for purposes of comparison. The foreign bulletins should also be worked up in the same way, for no matter how beautifully and completely they are turned out, they have this innate defect, that the distribution of pressure is contained in the same chart with the *simultaneous direction* of the wind. The distribution of pressure, temperature, humidity, &c., should be given on one special chart (*a*), and the wind condition on another chart (*b*). If both charts were drawn on thin paper, we might compare (*b*) for the 2nd, 3rd, and 4th of a month with (*a*) of 1st, 2nd, 3rd, 4th, 5th of the same month. They would show, for I have proved this without possibility of contradiction more than 15 years ago, that (*b*) is more dependent upon (*a*) than (*a*) upon (*b*), so that the conditions of wind for one day are regulated by the conditions of pressure of a previous day. But as, in the foreign bulletins that I have named, we only find the conditions of wind and pressure for the same day, we have not yet got a good representation of the dependence of wind on the distribution of pressure.

Naturally I do not assert that those who issue the charts have not themselves discussed them thoroughly. On the contrary, we know the investigations of Messrs. Scott, Buchan, Mohn, and Loomis, but no one has as yet given so clear and intelligible a representation of the results for a third person. In one word, we have as yet no published statistical comparisons of the probabilities deduced from the data given on the charts with the results for the following days.

Although for comparisons such as these to which we have referred, the above-named rule is as yet the best, we shall yet have furnished no answer to the much more important questions proposed by Professor Dove. How many kinds of storms are there? How do atmospheric depressions take their rise? For these of course are not generated by themselves, but are produced by previous atmospheric currents of the magnitude of the polar and equatorial currents. To answer this question we should want to know the distribution of the wind and of pressure over the whole hemisphere, and also in the upper strata. In this respect the most interesting question is: Who will be able to give an answer within any reasonable time?

Moreover, we must take into consideration the course of mountain chains, the limits between oceans and continents, and the whole problem so complicated, and the observations so incomplete, that we must think ourselves fortunate if we can only contribute something to render the solution more simple for our successors.

II.

The gradients, a term which we owe to Mr. Stevenson, of Edinburgh, and which give in figures the difference of pressure, must first be mentioned. The wind blowing at one time, at one place, is soon at another, it only requires five hours to get from Greenwich to Utrecht, but the gradients give a much longer indication of the wind, at times as much as 24 or 48 hours in advance. You calculate for each day the mean normal level for the place and the instrument; see the deviation of the observation, divide the difference of the deviations of the two places by the distance between the places, this gives the gradient between the two places.

I have fully proved in my "Suggestions" that it is inadmissible with heights of any magnitude to reduce to sea level, and I should have illustrated this by example if I had not thought it well to omit such a step out of regard for some highly valued physicists and fellow workers. There is also a certain difference of opinion between Professor Mohn and me, but this is in the second place. Perhaps I should confess myself entirely convinced; but under any circumstances we should not reduce to the sea level. I know myself the normal levels sufficiently accurately for every place in Europe, so that we can trust the deviations.

But now the question comes between what places are the gradients to be given, for between n places there are $\frac{n(n-1)}{2}$ gradients.

I give one gradient exactly by the position of the Aeroklinoscope, but which one?

If we have only got the deviation for three places we may erect the deviations as perpendiculars to a plane of the normal readings, and for this it is admissible to take the map of the district; the plane itself is determined by the three points, and so is its "strike"* and inclination.

The position of the Aeroklinoscope which indicates this is perfectly definite.

This definiteness is lost as soon as we have to deal with four or more stations. In the case of four stations besides the central station, as in Holland, I have the deviations at Maestricht, Flushing, Helder, and Gröningen, and lay down the probable plane through these points.

Besides, we give attention to the question of whether Utrecht, the central station, has a reading higher or lower than corresponds to that which would be given by the perpendicular to this probable plane. I cannot with an Aeroklinoscope of my description show, or make visible at a distance, more than this.

We might add simple signals to show if in Scotland, England, France, or Prussia, the deviation were more or less strongly positive than in Utrecht. At present I have only made this visible at the foot of the Aeroklinoscope, and this, therefore, benefits inhabitants and the sailors of the place itself.

At the central station (I have a model for it in Utrecht) we should for all places which furnish observations lay down perpendiculars in proportion to the deviation on the chart, and draw a surface through these points. We do it here for every three successive days or periods of observation, and compare the configurations which are produced in this way. Our problem is to reproduce this configuration as closely as possible in the harbours.

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* "Strike" is a geological term, and is the bearing of a horizontal line drawn in the plane.

The more regular is this configuration, *i.e.* the better we can represent it by a simple plane or a conical surface, the more certain is the problem. The more irregular it is, *i.e.* the more depressions and elevations appear on the surface, the more uncertain it is. But in this case no strong wind arises until the configuration has taken another character, and *e.g.*, two or more depressions have run together and formed a great depression.

III.

We should proceed in the same way and by the same rules as Professor Dove has proposed, and as all have adopted after him. In winter the temperature is higher during storms in our part of the world, because the S.W. wind at that time has a high temperature. In summer, when, however, storms are rare, the east wind is the warmest. At this season temperature teaches us little or nothing. We must as yet consider it undetermined whether or not great humidity can appear as the cause and forerunner of the storms, as Clement Ley, Mohn, and Reye maintain. I must admit that the theory of Professor Reye, of Strasburg, has deeply interested me.

IV.

The answer is twofold, for the requirements are twofold.

For the theoretical investigations we ought to be able to consult all the deviations and observations, but this can be done subsequently.

For the practical question, which in my opinion has been almost answered by each one of us for his own country, we cannot use too large a mass of material, for there is no time for working it up properly, and besides it costs too much to exchange so many telegraphic reports. It would be enough to adopt such an arrangement as Mr. Scott has now with France, Holland, and some other countries, viz., that each director of a district sends to his neighbours, and receives from them intelligence of the greatest and least deviation* in his district with the places where they are observed, and with the information as to whether there is any strong wind in his district, and from what point.

V.

No prophecies, if we do not wish to bring the matter into discredit. It is impossible for the director to say at what place on his coast the wind will blow first or hardest, if he does not wait till the storm has already begun at a slight distance from the coast, and then it is too late. As I have said, often well-marked squalls have been felt at Flushing or Helder only five hours later than at Greenwich, and if storms have not already begun, we cannot assign their direction so minutely as to be able to say that the gale will blow north or south of the Hague.

Besides, such a prophecy is considered as an official announcement. We should only give the conditions. Every one has the well-known rules for deducing his results from these conditions. If he wishes he can make further enquiries, and see from the behaviour of the barometer at the place where he is, whether the conditions are becoming more favourable, or the contrary. Every one of us believes that he will be able to forecast the weather one of these days, but the time for that has not yet arrived.

Did not Professor Dove himself say that many storms he had certainly foretold, but many he had not.

In addition, we must remember that any one who has to forecast weather, if he does it in earnest and conscientiously, is in great danger of going off his head through nervous excitement. I therefore answer the second alternative of Question V., "or should we confine ourselves, &c." affirmatively, and think that our efforts should be directed to the ultimate possibility of answering the first alternative in the affirmative also.

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* I do not telegraph "deviations," but "readings reduced to sea level."—R. H. Scott.

VI.

In regard of this, application must be made to the Governments. If we are convinced that ships in harbour derive benefit from communications of the conditions of weather, it is equally certain that ships at sea, when they pass islands, lighthouses, &c., can make use of them, especially when they are coming into port. The simpler are the means of conveying such information, the easier will it be to supply lightships and lighthouses with the requisite apparatus and with telegraphic wires. A ship bound to Hamburg from the Atlantic will prefer to wait a day if she learns at Lands End that the barometer is very low in Holland, with great heat in Spain, but other conditions would modify this conclusion.

Addendum, July 1874.—Professor Buys Ballot wishes to express his entire approval of Professor von Oettingen's proposition VI. He is now able to convey in a simple and intelligible manner, and to a great distance, 54 different signals by means of the apparatus invented by Major Kronhout.

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